~~Estimation of~~ Groundwater Recharge to Aquifers of Sana'a Basin, Yemen

by

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Dedicated to my mother,

Fatima A. Al Zari

Abstract

The purpose of the study is to understand quantitatively the spatial distribution of groundwater recharge in the Sana'a Basin, Yemen i.e. irrigation recharge, wadi recharge and urban recharge and to assess the impact of these components on the groundwater quality.

A combination of field measurements and modelling was used to determine the irrigation return for several crops and soil types. Over the basin, the total return flows, between 20 to 40 % of the water applied, are about 30 MCM/year.

A method was developed to calculate recharge through ephemeral wadi beds using an indirect approach, requiring only daily rainfall data and geomorphological observations. The technique combines a rainfall-runoff model with calculation of daily water balance for the wadi channel. The method was applied to two wadis with sufficient subsurface data to estimate groundwater recharge independently from calibration of groundwater models for the shallow aquifer. The values of infiltration calculated by groundwater flow model were in good agreement with the results of the channel water balance model.

Regression analysis was used to derive a generalised relationship between recharge and wadi flows. Application of this technique allows extension of wadi recharge estimates to numerous ungauged wadis over 20 years. Wadi recharge over the Sana'a basin is erratic and varies between 129 MCM and 3 MCM with an average of 38 MCM/year.

An inventory of abstraction by private wells in Sana'a city, has allowed an improved estimation of urban recharge over the last 20 years, an average of 60% of the water abstracted (76% supplied).

Water chemistry indicates that the shallow aquifer within the plain and lower reaches of major wadis has been polluted. However, dilution is taking place through mixing with the deep fresh water through the boreholes.

Total annual recharge varies between 143 MCM and 21 MCM with an average of 66 MCM. This represents a significant amount of the annual average abstraction of 82 MCM. Previous estimate of recharge to aquifers of the basin has been less soundly based.

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1 INTRODUCTION

1.1 Background

Groundwater exploration and use is of fundamental importance for logical economic development in the Sana'a Basin because of the normal unreliability of surface water supplies and the rapidly expanding urban, agricultural and industrial water requirements. Definition of groundwater recharge mechanisms and characteristics are essential for development of a resource management policy and the lack of control on groundwater abstraction by the decision makers is mainly due to unreliable and in some instances contradictory, information about recharge figures.

The declining groundwater table in the well field area and southern part of the Sana'a plain has led some investigators to the conclusion that abstraction is exceeding replenishment and that mining of storage is taking place. However, in the early 1970s, before construction of the well field and before large scale abstraction for irrigation, a declining water level was reported, and Italconsult (1973) reported that about 15% of the dug wells inventoried were dry. Mosgiprovodkhoz (1986) concluded from their study during 1984 that a surplus resource of about 15 MCM/yr was left for further development. The variations in these estimates of the resource stem from differences in the calculation of recharge.

Although recharge mechanisms are reasonably well known, deficiencies are evident in quantifying the various elements, (Simmers et al, 1988). Several techniques are available for estimation of recharge, however, all have been developed for humid regions, and their applicability to arid regions is still being tested. This is mainly due to the groundwater recharge in arid zones, both sources and processes, being different from those in humid regions. The groundwater recharge is usually intermittent and concentrated in certain areas, and hence point methods are preferable for more detailed studies of arid zone recharge. However, this causes a further unresolved problem, that is regionalization of point observations.

Of all the factors in the evaluation of groundwater resources, the rate of aquifer replenishment is one of the most difficult to derive, especially when estimation with inadequate data is required. It is well known that there is no single comprehensive method to estimate groundwater recharge, and using more than one method is recommended. First a literature review was carried out, followed by field data collection over a period of 9 months. The methodology of recharge determination was developed after considering several factors; such as accuracy required, applicability of a method, availability of data, time etc.

1.2 Aim and objectives of the study

The primary purpose of the study is to understand quantitatively the spatial distribution of groundwater recharge components, including both natural and man-induced recharge. A secondary aim is the assessment of the impact of the man-induced recharge in the groundwater quality. To achieve these aims, the following objectives have been pursued;

- understanding of the groundwater system, through hydrogeological and hydrochemical techniques;
- definition of the reliability and variation of the rainfall and its consequences for recharge;
- definition of the most important recharge mechanisms and sources in the Sana'a Basin;
- evaluation of actual evapotranspiration though determination of canopy resistance (rc) for main crops in the basin;
- evaluation of irrigation recharge through numerical modelling of the irrigation return flow;
- estimation of wadi flow through rainfall-runoff analysis;
- evaluation of wadi recharge by channel water balance and modelling recharge through wadi bed;
- quantification of the amount of man-induced effluent infiltrating within the urban area;
- water quality distribution within the basin, and preliminary assessment of recharge water quality by area over the basin, for man-induced recharge components and the expected dilution by natural recharge component;
- analysis of the inter-relationship between recharge, abstraction and the decline in groundwater level.

1.3 The structure of the thesis

Evaluation of groundwater recharge in the Sana'a basin requires clarification of the natural and artificial water cycle for the basin. Each item in the water balance of the basin is thus subject to analysis and evaluation. The first three chapters of this report provide background information about the hydrometeorological system and the geological-hydrogeological systems in the Sana'a Basin.

Each item of the hydrometeorlogical system is described in Chapter 2. An outline of the topography and drainage system is given first, followed by more detailed information on the rainfall over the basin. Local actual evapotranspiration was evaluated from the water budget method whereas the regional evapotranspiration was computed by Penman-Monteith equation. Detailed information is given in Appendix A.

An outline of the geology and aquifer systems in the basin is described in Chapter 3.

Chapter 5 describes wadi flow characteristics and a rainfall-runoff model with details given in Appendix C.

Evaluation of the three main groundwater components over the basin, irrigation recharge, wadi recharge and urban recharge are described in chapters 4, 6 and 7, respectively. Each chapter provides background information, followed by description of the field procedure, the collected field data, approach, analysis and summary of the results. Detailed information with respect to the collection of field data and the final results are given in Appendices B, D and E.

A similar format is used in chapter 8 to describe the hydrochemistry of groundwater within the basin. Detailed results of analysis are given in Appendix F.

Chapter 9 describes the distribution of the total annual groundwater recharge and abstraction by areas.

Then an attempt to define the inter-relation between recharge, abstraction and water level changes is described. The detailed results are given in Appendix G.

Chapter 10 presents the conclusions and recommendations for further required investigations.

1.4 The study area

The Sana'a basin is the largest of the intermontane plains in the Central Highlands of Yemen, and covers some 3209 km^2. It lies between 15°00 - 16°00 N and 43°45 - 44°45 E and the location is shown in Figure 1.1. The plain, in which the capital city of Yemen is located at an elevation of 2200 m above sea level (asl) is surrounded to the west, south and east by plateaux with elevations up to 800 m above the plain, dissected by several valleys.

A very high annual growth rate of 11% of the population of the Sana'a city was reported between 1975-1986 (Grover, 1986). In December 1994, the population amounted to 972,011 people (Pers. comm. 1995). Compared with a population of 427,185 in 1986, this indicates that the population has apparently grow at an average rate of 9.57% per year since 1986, when there were 67,965 houses with an average household size of 6.29 people (CPO, 1990). Recent houses numbers are unavailable. The rural population in 1993 was estimated as 420,674 people.

Administratively, the Sana'a Basin falls within part of 10 of the 35 districts comprising the Governorate of Sana'a. The Districts are: Bani Hushaish, Bani Harith, Bani Bahlul, Sanhan, Khawlan, Bani Mattar, Arhab, Hamdan, Eyal Seraih and Nehm. Only Bani Hushish falls entirely within the Basin.

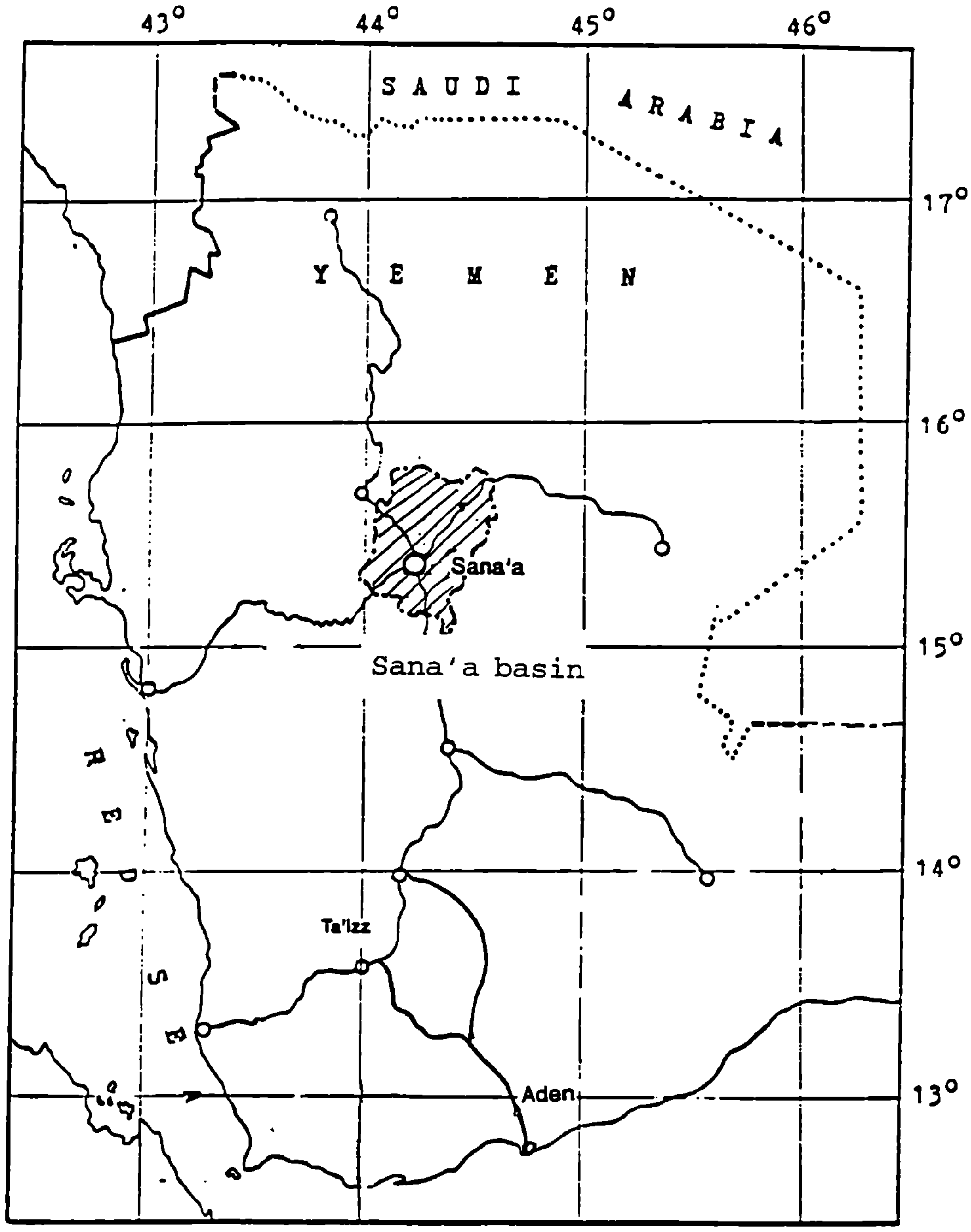


Figure 1.1 Location of Sana'a Basin

1.5 Previous Work

Several groundwater studies have been undertaken in the Sana'a basin since 1972. Recharge estimates made by these studies are summarised in Table 1.1. Most of these estimates relate only to the wellfield area; only the Mosgiprovodkhoz (1986) study covered the whole basin. The percentage of rainfall method to estimate recharge depends on the area, the percentage adopted and annual rainfall estimate applied. The Darcy method used by most is not expected to be very reliable, since it is normally only suitable for steady state, isotropic conditions and uses head gradients based on poorly defined water level contours and uncertain transmissivity values (TSHWC, 1992). The steady state condition was probably satisfied during 1972 (used in model calibration by TSHWC, 1992), as the water levels were not affected much by abstraction at that time. However, the transmissivity may not be representative for the Cretaceous Sandstone.

The components of the sum of the annual groundwater inflow to the basin in million cubic metres, estimated by Italconsult (1973) are as follows; Cretaceous sandstone - 59 MCM (26 WEST, 33 EAST), Quaternary deposit south of the plain - 2 MCM and volcanic aquifer - 3 MCM. They reported that the figure for the eastern part of the wellfield was only an approximate value, and needed further confirmation. The amount of recharge to the Cretaceous sandstone (59 MCM) would require a catchment area of 5000 km^2 when it is related to annual rainfall and 5% infiltration coefficient (or 18% of rain, with an area of 1100 km^2).

Howard Humphreys (1977) assessed recharge in the wellfield area to be 44.8 MCM using the Darcy method, that is 16.8 MCM for the western area and 28 MCM in the eastern. In 1979 with new data on aquifer transmissivity and head gradients, Howard Humphreys adjusted the value for the western wellfield area to 30.9 MCM, and the value for eastern wellfield remains, thus the total inflow to the wellfield area was calculated as 58.9 MCM, which supported the Italconsult estimates in 1972. Dar Al-Handasah (1978) estimated recharge for the western well field area as 18 MCM using the Darcy method.

Charalambous (1982) attempted to conceptualise recharge processes by assuming that recharge is derived indirectly from runoff in the wadis draining to the northern basin. As reported by Nash (1991), he used an infiltration coefficient of 10% of annual rainfall of 330 mm, and over an area of 700 km^2, thus the recharge volume is 25 MCM/year. By 1983, Howard Humphreys estimates of recharge quantity had changed. By assuming recharge through the Tawilah only, they estimated recharge to be 25.23 MCM along North eastern outcrop over an area of 750 km^2. They emphasized, however, that an accurate recharge quantity was still unknown.

A reconnaissance isotope study was carried out in 1984 to identify areas of groundwater recharge by Jungfer (1987). Water samples were analyzed for tritium, O-18, deuterium and C-14. The results showed that, except for isolated areas in the southern and western portions of the basin, the Tawilah aquifer has received little or no recent recharge.

Mosgiprovodkhoz (1986) assigned different percentages of annual rainfall, varying from 5 to 9 %, contributing to recharge in various hydrogeological zones (60 zones), but without differentiating between the direct and indirect recharge components. They estimated annual recharge as 55.87 MCM (51.73 infiltration and 4.14 lateral inflow from outside the surface catchment), which was mistakenly reported by all following investigators as 63 MCM, after a report by Dubay et al (1984), which was based on initial results from the Russian study.

Table 1.1 Summary of previous estimate of recharge in Sana'a basin

Study	Date	Area km^2	Method	Recharge MCM/yr	comment
Italconsult	1973	1200	Darcy	67	(59 for Sandstone)
Howard Humphreys	1977		Darcy	45	wellfield area
Howard Humphreys	1979		Darcy	59	wellfield area
Dar al-Handasah	1978		Darcy	18	western wellfield
Jungfer	1984		isotopes	Trace	Sana'a plain
Charalambous	1982	750	%rainfall	25	Indirect recharge
Howard Humphreys	1983	750	%rainfall	25	S.S outcrops
Mosgiprovodkhoz	1986	3209	%rainfall	56	zones
SAWAS	1989	143	Darcy	4	southern plain
TSHWC	1992	2400	misc.	42	see text

Recharge estimates by TSHWC (1992) have been derived using an empirical approach, based on either a percentage of rainfall or flood runoff, using the daily rainfall records for Sana'a and Shibam. The assumptions employed are; (1) indirect recharge is taken as 75% of flood runoff where precipitation is less than 250 mm, (2) direct recharge is taken as 3-5% of precipitation in areas with precipitation of more than 250 mm, and (3) where applicable, recharge was taken from previous detailed groundwater studies. The total recharge to the basin is estimated to be 42 MCM/year.

Previous estimates of recharge in the Sana'a basin relate to different areas, based on an inadequate conceptualisation of the systems, and use different methods and inadequate data.

1.6 Land Use

There has been rapid economic development in the Sana'a region since the Republican Revolution of 1962. The Sana'a region is arid to semi-arid, so agricultural crop production can be greatly increased by irrigation. Irrigation return represents an important component of the recharge. So data on crop patterns, water use, and the physical characteristics of the soil, which also give an idea of relative infiltration rates, are important variables in recharge estimation.

As delineated by Mosgiprovodkhoz (1986), the basin's surface area is 3209 km^2, of which 10.3% is plain and 89.7% mountainous. Classification of the Sana'a Basin has been carried out on the basis of soils, land use, and agro-ecological data. On the basis of the land use, the basin is divided into four main classes, with some classes subdivided into subclasses. The main classes are given in Table 1.2. An increase in the agricultural land by 1% a year has been used (Chaudry and Turkawi, 1990) to estimate the present agricultural land. A similar growth rate was used for the urban areas. These increases have been deducted from the range land, but the unusable land was assumed to be constant, as it represents steep slopes and inaccessible mountain summits.

Table 1.2 Land use classes in the Sana'a basin (modified from Mosgiprovodkhoz, 1986).

Class	Area, Km^2 1993	Area, Km^2 1986
agricultural land	1165.4	1065.5
Urban/ built up land	133.0	122.8
Range land (natural pasture)	762.0	871.6
Unusable land (rock outcrop)	1149.0	1149.0
Total area	3209.0	3209.0

On the basis of soil type, the Sana'a basin has been classified into 7 different soil types. The descriptions and the spatial extent of each of these soils are given in Chapter 4. Agricultural land was further subdivided into cultivated (active cropland) and fallow (inactive crop land). The extent of each type over the period between 1972-1993 is described in chapter 4.

The farmland within each region was further subdivided into subregions that delineate the main physiographic units of the basin.

Table 1.3 Physiographic Regions of Farmland. (after Mosgiprovodkhoz, 1986)

Subregion	Area km^2
Plateau	236.7
Terraced slopes	371.9
Wadi bottom	155.1
Highland plain	301.9

The Yemeni rainfall harvesting schemes explain how rain-fed agriculture is still possible in areas that would normally be far too dry for it. Four systems can be distinguished for the rain-fed agriculture (TSHWC, 1992); (1) bunded fields without rainfall harvesting areas found particularly on hill tops. The bund prevents the outflow of excess rainfall. (2) bunded fields with rainfall harvesting areas are found in the moderate slopes of wider valleys. The size of rainfall harvesting areas varies and can be considerable, bunds direct the overflow to the field and excess water is given to the field located downhill. (3) Terraces on slopes tend to increase going from the north-east to the southern part of the basin, following the rainfall trend (Mosgiprovodkhoz, 1986). This implies that terracing is found more where there is higher rainfall that can sustain the soil moisture content. (4) Field bunds in wadi bottoms are common where the wadis are wide and not too steep. Large debris and rock fragments are usually removed. This type of water harvesting not only uses the direct overflow from man-made, water-harvesting areas, but also from runoff that may accumulate in the natural drainage system. The importance of these schemes is not only for the agricultural production, but they also have an important role in the direct (irrigation return) and indirect recharge to the groundwater, the latter through their effects on the runoff characteristics.

Two main runoff zones are distinguished in Sana'a basin: runoff creating zones and runoff absorbing zones. The surface runoff generated in the mountain ranges drains towards the wadi bottoms, where it is normally retained in the internal sub-basin (main wadi), and only in wet years, flood water reaches the main channel in the plain. The runoff characteristics are strongly influenced by terracing of mountain slopes. Runoff absorbing zones strongly affect the flood routing characteristics i.e. the modification of flood waves as they travel along a wadi. These characteristics, together with the availability of data, have dictated the methods to be used in the estimation of indirect recharge in the basin. Seven different runoff characteristic zones are distinguished; four as runoff-producing zones and three as runoff-absorbing zones. The zones were delineated using data and maps from Mosgiprovodkhoz (1986), and 1:50,000 topographic maps (Survey Authority, 1986).

1.7 Water use and groundwater abstraction

This section gives background information about the water use and groundwater abstraction in the Sana'a Basin, through a simple review of previous estimates of water use in the basin. Only documents which were based on collection of additional data are considered. A detailed description of the analysis and evaluation of the extracted groundwater for irrigation and urban use is given in chapters 4 and 7, respectively. This is because groundwater abstraction is one of the most important components of the water budget and is required in the estimation of the return flow components from irrigation and urban recharge. Distribution of groundwater abstraction by area is described in chapter 9.

Hand dug wells and qanats (tunnel system of collecting ground water) have been in use in the Sana'a basin since ancient times. However, the amount extracted by dug-wells from the shallow alluvial aquifer must have been less than the subsequent periods, as water was being lifted either with animal or man power. The average Yemeni family, especially in rural areas, uses relatively minute quantities of water in the household. The people have inherited that low usage from the pre-revolution era, when bringing water was quite a difficult task. Within Sana'a city, the population was served by hundreds of dug wells. Similarly, approximately 90% of all cultivated land in the Sana'a basin was rainfed. The use of stored groundwater tapped through hand-dug wells constituted an almost negligible demand. However, this trend has changed since the 1960s, as a result of the pressing need to increase agricultural output, which led to the advent of drilled wells and the diesel-driven pumps.

The first estimate of the amount of water used was in 1972, by Italconsult (1973). The domestic use was estimated to be 1.4 MCM (Table 1.4) annually, with 0.66 MCM/year for industrial use, as based on the government Master Plan. The abstraction for irrigation was estimated as 4.6284 MCM from well inventory. Considering crop water use over the same area and based on an agronomic study, Italconsult estimated irrigation abstraction as 3.876 MCM, with an acceptable average of 4.125 MCM. Italconsult could not estimate the rural domestic supply, claiming that most of wells were of combined use, for irrigation and rural supply and so this may explain the difference in the irrigation abstraction estimated by the two methods.

Note: the figure 6.4 MCM/year (Table 1.4) for irrigation includes the northern part of the plain, in which well inventory was incomplete and Italconsult assumed 1.8 MCM as abstraction for irrigation.

In 1972, out of the 1000 existing wells registered by Italconsult (1973), 30% (300) had been abandoned, 10-15% (125) were dry. Out of the working wells, 40-45% (about 230 including the northern plain) were equipped with pumps and the rest used man or animal power to lift water, usually to irrigate small plots of .05-.1 hectare.

The catchment for the Sana'a basin as defined by Italconsult, was about 1200 km^2, and covered mainly the plain, where the urban area is located. To compare their results with the subsequent ones, the ground water abstraction for irrigation in 1972 over the whole basin (i.e 3209 km^2) was required. As no aerial photographs nor satellite images were available to define the arable area, the farmland area was estimated as 943 km^2, by assuming an annual growth rate of 1% since 1972 and using data for 1984 provided by Mosgiprovodkhoz (1986).

If the results of the agronomy study provided by Italconsult (1973) are assumed to be a representative sample for the whole basin, the irrigated area in 1972 would be 2937 ha. Using same cropping pattern and water use for 1972, as Italconsult, the abstraction for irrigation over the whole basin was computed as 14.1 MCM in 1972.

Spring discharge was estimated as 3 MCM/year for 4 springs within the plain and their water was used to irrigate an area of 300 ha.

Table 1.4 Ground water abstraction in 1972 (Compiled and modified from Italconsult, 1973)

Water use	Over 1200 km^2 MCM	Over 3209 km^2 MCM
Private urban	0.64	0.64
Public places	0.70	0.70
Commercial	0.09	0.09
Industrial	0.66	0.66
Public urban	1.02	1.02
Irrigation	6.41	14.10
Total	9.50	17.20

The other regional estimate of groundwater abstraction, and the only study which covered the whole basin, was made in 1984 by the Russian project (Mosgiprovodkhoz, 1986) and was based on a well inventory. However due to the bad translation of the main reports and unavailability of Appendix 2 of volume 3, the Mosgiprovodkhoz estimation of ground water abstracted for irrigation became a controversial issue. Column 2 in Table 1.5 shows the summary of the abstraction in 1984 as reported by Grover (1986) who reviewed the data in the interim report issued by Mosgiprovodkhoz in 1985. The figure given for abstraction for irrigation has been criticised by most of subsequent investigators. For example, although Nash (1991) suspected Mosgiprovodkhoz might have corrected the abstraction for irrigation return, she estimated irrigation abstraction to be 43 MCM for 1984/1985 using an irrigated area of 11000 ha and Italconsult's water use coefficients. Al-Eryani et al (1992) suggested that the abstraction figure represents abstraction from the plain alone, and suggested 60 MCM as abstraction for irrigation on the basis of the existing wells in 1984. Appendix 2 of volume 3 (Mosgiprovodkhoz, 1986), which contains well inventory information, was available for the present study and a review was carried out to clarify the Mosgiprovodkhoz estimate.

According to Appendix 2 of volume 3 (Mosgiprovodkhoz, 1986), the Russian team registered 1227 dug-wells and 872 boreholes. Out of the registered wells, 912 dug wells and 806 boreholes were in operation. Using information on the daily abstraction for working boreholes and wells, the total abstraction by boreholes was computed as 48.238 MCM and by dugwells 10.613 MCM, with total of 58.852 MCM.

According to information on water use, rural water supply was calculated as 3.74 MCM (2.775 MCM by boreholes and 0.962 MCM by wells) and the rest 55.1 MCM, for irrigation and private abstraction within Sana'a city. Adding 9 MCM for public water supply gives a total groundwater abstraction over the Sana'a basin in 1984 of 67 MCM, which is almost equal to the "calculated usable water resource" in the final report (Mosgiprovodkhoz, 1986).

The number of the existing wells in the basin in 1984 was 1957 wells and 1768 boreholes (total 3725), as reported by Grover (1986) and different from the numbers in the Mosgiprovodkhoz inventory. Mosgiprovodkhoz used the sum of the daily abstraction for wells which were located close to each other. The number of boreholes are noted beside the daily abstraction but it is believed that a number of boreholes were mistakenly not reported, and some were reported with high daily abstraction of more than 1000 m^3 .

The abstracted water for irrigation in 1984, according to Table 1.5, was 24.196 MCM. Mosgiprovodkhoz (1985) noted that irrigation efficiency was generally low in the basin, with estimated losses of 46% of all groundwater pumped for irrigation (Grover, 1986). Without correcting the reported abstraction for the irrigation return to the aquifers, the abstraction for irrigation would be 44.8 MCM. A similar figure of 43.9 MCM for irrigation water consumption was obtained from agronomy results (chapter 4) as well as that calculated from well inventory data (Mosgiprovodkhoz, 1986).

Table 1.5 Groundwater Abstraction in Sana'a Basin.

Water use	Mos.1985[1] m^3/year	Modified,1984[2] m^3/year
Urban area;		
1. NWSA-public water supply	9,125,000	9,114,282
2. Private wells domestic use	1,825,000	5,475,000
3. Irrigation	5,475,000	1,825,000
4. Industry	1,825,000	1,825,000
Rural water supply	4,015,000	4,015,000
Irrigation water[3]	29,671,000	43,870,000
Total	51,936,000	66,125,000

1 as reported by Mosgiprovodkhoz in 1985, after Grover (1986).

2 modified abstraction without correction for irrigation return.

3 Including the irrigation within Sana'a city

The distribution of the abstraction in the urban area, as reported in Table 1.5, was found to be inconsistent with the estimates of 1972 and 1993. This is a result of underestimation of the population of the city in 1984. The corrected distribution of abstraction for urban use is discussed in chapter 7. The total abstraction for urban use was divided into 5.475 MCM as private abstraction for domestic use, 1.825 MCM for industrial use and 1.825 MCM for irrigation within Sana'a city.

Rural water supply, (Mosgiprovodkhoz, 1986) was 4 MCM, used by 240,300 people with a consumptive use of 45 l/c/d. The corrected population was estimated from census results of February 1986, as 315,000 people. Using a similar annual growth rate for Sana'a governorate of 5.4% between 1975 and 1985 and 3.45% between 1986 and 1994, the population was extrapolated until 1993. Average consumptive use was estimated at 35 l/c/d, between that reported by TSHWC (1992) of 25 l/c/d and that used by Mosgiprovodkhoz (1986). When the estimated use is multiplied by the corrected population, the figures for rural supply water abstraction agree with those obtained from the well inventory data (Mosgiprovodkhoz, 1986). The abstraction varies from 2.3 MCM in 1974 to 5.4 MCM in 1993.

The spring discharge in 1984 was estimated as 7.8 MCM and mainly used for irrigation (Mosgiprovodkhoz, 1986).

The use of water continues to rise and farming practices have changed dramatically. Land which was formerly rainfed has been placed under irrigation. This change has became more pronounced since 1987 when the government abandoned importation of any vegetables and fruit, in an attempt to encourage the local farmers. Abstraction for irrigation over the Sana'a basin in 1993 was estimated as 149 MCM, based on crop water use and irrigated area. The figures for abstraction for irrigation and rural supply during 1992 and 1993 were verified from recent well inventory data over parts of Sana'a basin and carried out by JICA, (Japan International Co-operation Agency) in 1992 and by SAWAS (SAna'a WAter Supply), which is a Yemeni-Dutch project.

In the urban area, the piped systems make water more accessible and convenient, and hence consumption of water has risen. The total urban consumption in 1993 was estimated as 29 MCM, using the results of a recent well inventory of the urban area carried out as part of the current research between May and August 1993.

In summary, best estimates of annual groundwater abstraction over the basin for various sectors is illustrated in Figure 1.2.

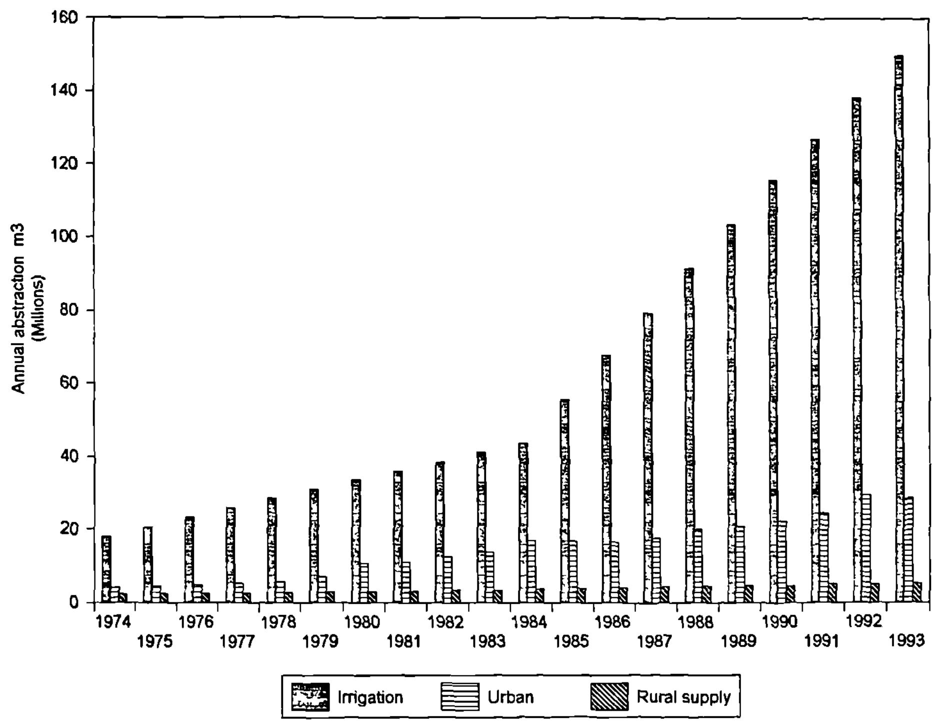


Figure 1.2 Annual water use over the Sana'a Basin

2 HYDROMETEOROLOGY

2.1 Physical Environment

2.1.1 Topography

The topography of the Sana'a basin was greatly influenced by its geological evolution, involving tectonic processes and volcanic activity.

In the north, where the Amran Group outcrops, the area is represented by a high plateau with a general gentle dip (1-3°) northwards. At the boundaries of the basin, elevated plateaus and mesas alternate with wadis cutting through them. These wadis in most cases run along the tectonically weakened zones and often have a canyon-shape (50-100 m width), and rarely are of trough shape 'U-shape' (200-300 m wide). Secondary valleys are mainly V-shaped, frequently with "hanging mouths" which testify to the area's higher rate of uplift, as compared with the rate of erosion of the hard carbonate rocks by water courses. Most of the area is mountainous desert topography. The watersheds between the valleys look like mountain plateaus, dissected by the valleys of higher order wadis.

Where the Cretaceous Sandstone outcrops, the topography becomes more pronounced as the sandstone is less resistant to weathering and erosion than the limestone. Wadis here are characterized by a U-shape up to several hundred metres wide, and only acquire a V-like shape in their upstream reaches. The mountain summits are often shaped like ridges, but closer to the watersheds, they are shaped like plateaus with absolute heights from 2300 to 2817 m.a.s.l. The mountain slopes formed by sandstone and shales of Mesozoic age, vary in steepness from 15°-30°, but toward the foot of the mountain become flatter by several grades.

The varying amplitudes of lifting of individual tectonic blocks, as well as the uneven distribution of the volcanic cones over the area, are responsible for the step-like arrangement of the old surface of weathering. The wadi valleys developed over the volcanics are canyon- or V-shaped in their upstream reaches, but in their middle and lower parts, the valleys reveal a U-shape or flattened profiles. Their bottom width varies from tens to several hundred metres. The main primary wadis embrace a dense network of secondary wadis. The gradient of the wadis becomes gradually flatter toward the downstream direction.

The Quaternary basalt forms a smooth topography of gently sloping surfaces, with numerous volcanic cones. The elevation of these cones is usually about 250-300 m above the plain.

2.1.2 Drainage system

The Sana'a basin forms the upper part of the catchment of Wadi AlKharid, a sub-catchment of the Wadi Al-Jawf. The hierarchy of Sana'a basin, based on valley shape and runoff, has been divided into two main types of catchments. The primary wadis have well developed valleys, with a trough-shaped configuration in the middle and lower reaches and discharge their flow into the central plain (Sana'a plain). These include 11 wadis; Dhar, Hamdan, Gabir, Hizyz, Akhwar, Gyman, Asfal, AlRawna, Rujam, AlSir and AlMahjir.

Figure 2.1 Drainage system of the Sana'a basin

The second type of catchment was grouped into three regions, A, B and C. Region A consists of three primary wadis with canyon-shape; Khulga, Alhadda and Alma'adi, in the north eastern part of the basin (over the Amran Group), which discharge their flow in Wadi AlKharid. Region B consists of minor wadis with undeveloped valleys and with short channels, developed over the Quaternary volcanics in the north western part of the basin. Region C is the central plain of the basin and consists of Wadi Alsyla, the main channel of the basin, and minor wadis developed at the rim of the surrounding mountains, which discharge their water into Wadi AlSyla (e.g. Wadi AlSurf, Hada, lower reach of Wadi Dhar). However because of their small catchment area and their less distinctive channel, the flow is small and rarely reaches the main channel.

Only one large permanent stream exist in the Sana'a basin; Wadi AlKharid, which is fed by springs of some 200 l/s to the north of the Sana'a plain. Wadi AlKharid collects runoff produced in the Sana'a area and flows further north to become one of the main tributaries of Wadi Al-Jawf system. The other streams in the study area are generally ephemeral, however some have springs that run over a limited part of their channel. A detailed description of three wadi sites is given in chapter 5.

In the western and southern parts of the basin the people have terraced the hillslopes in an effort to capture the rainfall and runoff. This has led to a decrease in the intensity of the floods. Nevertheless, these wadis are very important because they concentrate the rainfall in certain zones, i.e over wadi bottoms which tend to be runoff absorbing areas, where infiltration predominates.

The direct runoff produced in the Sana'a basin was reported by Mosgiprovodkhoz (1986) in probability of occurrence. However, Nash (1991) reported 29 MCM/year (9 mm/yr) (i.e 2.7% of the precipitation) as an average estimate for direct runoff based on Mosgiprovodkhoz reports. The figure estimated in the present study was 20 MCM/year at the outlet of the Sana'a basin (chapter 5). A recent estimate by TSHWC, (1992) of the annual average runoff produced over part of the Basin (1925 km^2) was 44 MCM/yr (10% of average annual precipitation). The present study estimates an annual average of runoff from upland areas of 74 MCM (8.3% of average annual precipitation).

2.2 Climate

2.2.1 Sources and type of data available

Data on meteorological elements were collected from Mosgiprovodkhoz (1986) reports, which combined all the available meteorological data in the Sana'a basin for the period before 1983. Except for their own measurements between August 1983 and July 1985, all other data were reported on a monthly basis. Daily rainfall data for various rain gauges, up to 1990, were obtained from the data bank of the Technical Secretariat of the High Water Council (TSHWC). Daily meteorological elements (rainfall, temperature, sunshine, relative humidity, atmospheric pressure, wind speed and radiation) recorded between 1986 and 1993 at Sana'a Airport weather station, and daily rainfall data for

Mind and Daba'at rain gauges were obtained from the Civil Aviation and Meteorological Authority (CAMA). Meteorological data for the weather station AlIrra, between 1986 and 1989, were obtained from Ministry of Agriculture and Water Resources.

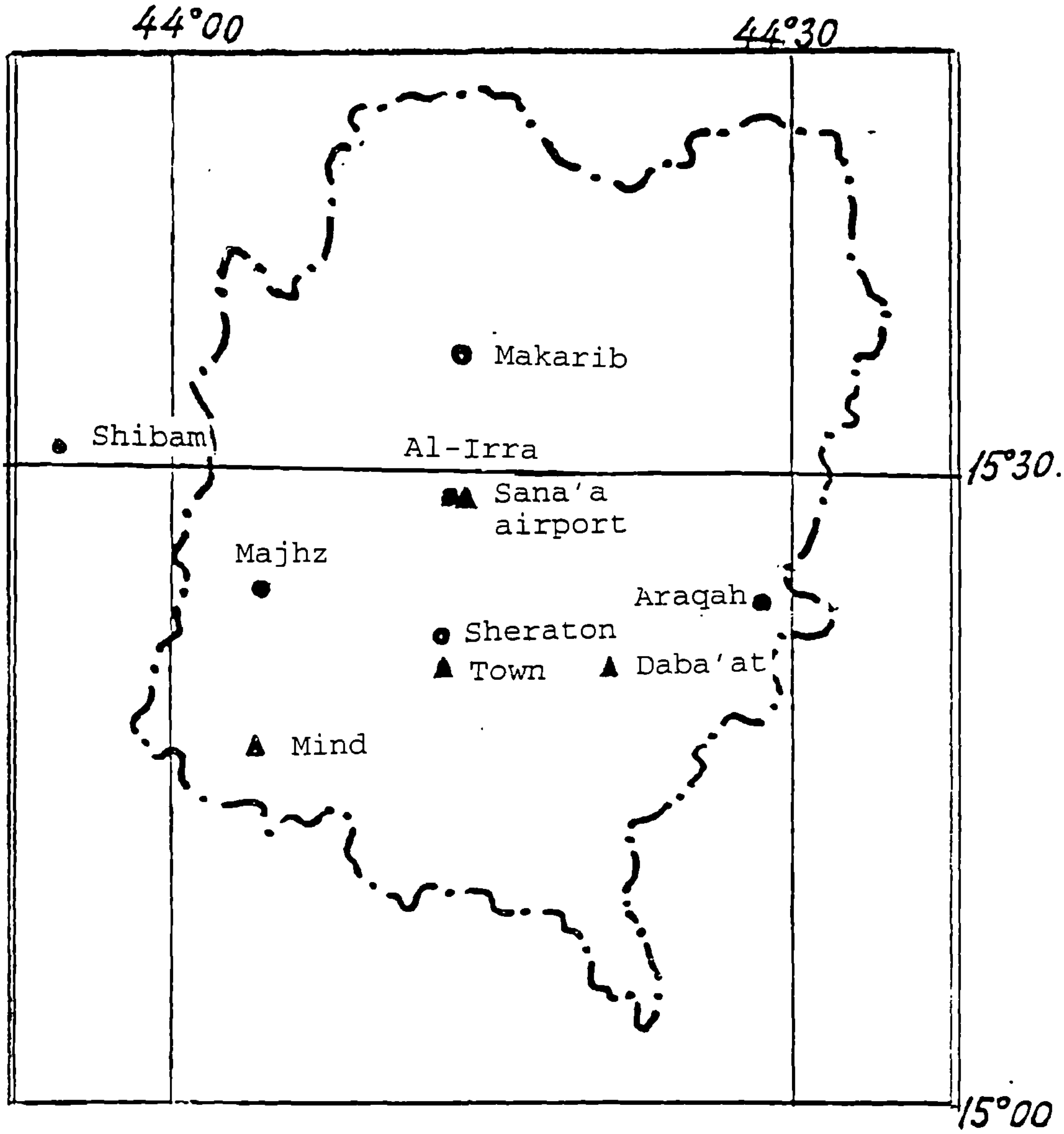
Table 2.1 gives details of the main stations used in the present study. The locations of these stations together with the other rain gauges constructed and operated during the Russian project (1982-1985) (Mosgiprovodkhoz, 1986) are shown in Figure 2.2. The records from these rain gauges have been used in interpolation of the missing data for the main stations.

All the recorded data have different gaps. The daily rainfall measured at Sana'a international airport weather station has missing data for the last quarter of 1975 and all of 1984. The records for Mind and Daba'at are incomplete. For Sana'a Town station, only a monthly record is available with two gaps, early in 1933 to 1936 and between 1948 and 1963.

Table 2.1 Rain gauge and Meteorological Stations. Location description and data availability.

Station	UTM E km	UTM N km	Altitude m.a.s.l	Data* availability
Sana'a Airport	416,0	1710,0	2190	1974-1993
Sana'a Town	416,0	1697,0	2190	1933-1983
Mind	399,7	1690,2	2760	1972-1991
Daba'at	435,0	1698,7	2460	1972-1990
AlIrra	416,0	1710,0	2190	1986-1989

* All records with gaps, see text for details.



● Secondary station used to complete missing data
▲ Main weather station or raingauge used in the analysis

Figure 2.2 Location of Rain gauges and Weather station in Sana'a Basin

Other climatic parameters, temperature, relative humidity, sunshine, barometric pressure and maximum wind speed are available only from Sana'a airport weather station, for the period between 1986 and 1993 on a daily basis with several gaps. The monthly data record varies between 1974-1984. Data for 1985 could not be traced in any of the available reports. Daily records of relative humidity, temperature, solar radiation and wind speed are available for the period between 1986-1989 at AlIrra weather station which is located 300 m from Sana'a airport but also has gaps in the record.

Various methods are available to interpolate or extrapolate the rainfall records. Average weighting of rain gauge records from three nearby raingauge stations (Bayt Majhz, Sheraton and Makarib) Figure 2.2, constructed and operated during the Russian project (1983-1985), have been used to estimate missing daily rainfall for Sana'a airport during 1984.

The monthly total record for Sana'a Town station was extrapolated to 1993, from an exponential regression equation developed from the period of data overlapping (1974-1983) with Sana'a airport station.

A different approach has been used to complete the missing daily rainfall data for Daba'at and Mind. As the daily rainfall data was not correlatable (section 2.2.2.3), monthly linear regression analyses were carried between each of Daba'at and Mind and the Airport rainfall data for the period of data overlap, starting in 1974. The regression equation was used to estimate missing monthly rainfall. The daily rainfall was then computed by assuming a similar number of rainy days to Sana'a airport station during the month. This method was mainly applied to estimate daily rainfall for months other than during rainy seasons and for the complete year in 1992 and 1993. The use of Mind and

Daba'at records, although their data were not complete, is the importance of their location and altitude. Also they have longer record starting since 1972, and the missing data are mainly during winter months.

For the purpose of data verification as well as further evaluation, annual rainfall data for all stations located in and around the Sana'a area were used to perform double mass analyses. The double-mass curve method is based on the concept that a graph of the cumulative data of one variable versus the cumulative data of another is a straight line, as long as the relation between the variables is a fixed ratio (Searcy and Hardison, 1960). It was used for detecting non-homogenities in the record from the stations. Average values for a group of surrounding stations, have been used as the 'base station' against which individual stations have been compared. This has been done because when only two stations are plotted against each other, it is not possible to determine which station is inconsistent. No major breaks in slope can be seen which would have indicated that the data are non-homogeneous. Figure 2.3 shows the double mass curves for the annual rainfall data, from four stations within the basin; Airport, Town, Mind, and Daba'at and indicates the homogeneity of these stations. Further the representativeness of the data from these stations was measured through the calculation of the correlation coefficient,(r) as 0.87 for Airport and Daba'at and 0.7 for Airport and Mind, which indicates strong correlation between the stations. The completed daily rainfall series for Airport, Daba'at and Mind were used in daily rainfall analysis over the Sana'a basin.

As the other meteorological element are less variable than rainfall, a combined daily series for Sana'a airport weather station between 1986-1993 was used for the analysis.

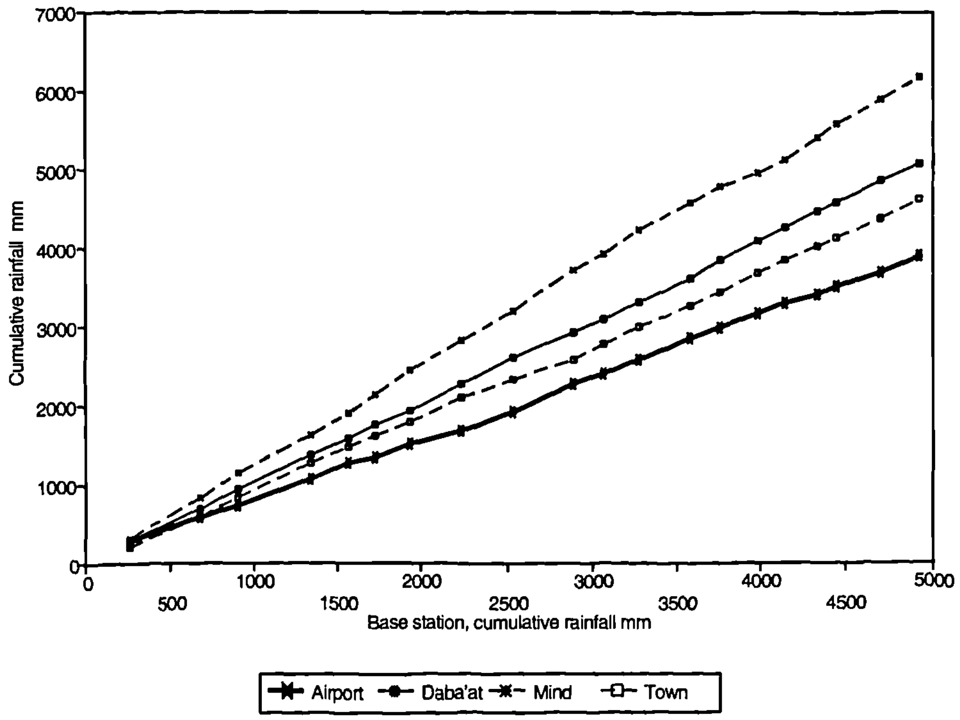


Figure 2.3 Double Mass Curve for Total annual rainfall for all station plotted against 'base station'

2.2.2 Rainfall

2.2.2.1 Origin of rainfall

From the available data and reports, two distinct rainfall seasons can be identified in the Sana'a Basin. The first season is a result of the Red Sea Convergence Zone (RSCZ) and occurs from March to May. The RSCZ is probably as a result of rapid heating up of the land surface, causing inland winds which lead to convection effects along the western escarpment(mountain front type). Humid air masses are lifted and carried eastward leading to rainfall events of high intensity but of short duration.

Before the second rainy season starts, during month of June, there is usually a transition, as the RSCZ retreats in front of a 'monsoonal' Intertropical Convergence Zone (ITCZ), which dominates the Sana'a area between July and September. The moist air comes from the south (Indian Ocean) and converges with the warm dry air from the north.

During the dry season from October to March, the weather is characterised by a persistent dry easterly to north-easterly airstream. The Mediterranean effect reaches Yemen once every few years and may cause some rain. The importance of each season within the basin is discussed in the following sections.

2.2.2.2 Seasonal and Annual Rainfall

In accordance with the major climatic influences, the 'spring season' is assumed to last from January to June (S1) and the 'summer season' from July to December (S2). A summary of the basic statistics for all stations is given in Table 2.3, which includes the seasonal and annual averages and the coefficient of variation of the seasonal and annual totals. During the first season, the south-western and south-eastern parts of the basin receive about 60% of their annual rainfall (Mind & Daba'at), the central and north eastern part receive 63% of the annual rainfall (Airport). The proportion of the annual rainfall falling during the second season is less than the first season for all three stations and varies between 37% and 40%. However, as would be expected the lowest percentage is in the east.

Italconsult (1973) showed that the summer rainfall was more important over Sana'a plain than the spring rainfall, during last 10 years of their study (1963-1972). The data between 1963-1983 (21 years) for Sana'a town showed that the share of each season in the annual rainfall is almost equal (51% and 49%). The share of each season in the annual rainfall for data from airport station during 1974-1993 (20 years) was 63% and 37% for the first and second rainy season. This implies that there has been a change in the distribution of rainfall between the two seasons during the last 30 years.

To verify this, the record from Sana'a airport station has been divided into two series, 1974-1983 and 1984-1993. Each series was then statistically processed. The results given in Table 2.2 confirm that there is a change in the contribution of each season to the annual rainfall. Within the last 20 years, the earlier period (1974-1983) was wetter with average annual rainfall of 234 mm, and the proportion falling in the second rainy season is greater than during the more recent period (1983-1993), which is drier with average annual rainfall of 160 mm. The variability of the second rainy season is higher for recent period, whereas the variability of the first season is becoming lower. The annual variation of rainfall is almost constant over the two periods.

Table 2.2 Statistical parameter for data from Sana'a airport station for two different periods.

	first season	second season	annual	proportion S1%	proportion S2%
1974-83					
Mean (mm)	133.6	100.0	233.7	.57	.43
Sd (mm)	74.8	70.0	97.4		
Cv	0.6	0.7	0.4		
1984-93					
Mean (mm)	108.0	52.2	160.1	.68	.32
Sd (mm)	52.7	45.5	58.1		
Cv	0.5	0.8	0.4		

It can be concluded that the importance of the second rainy season has decreased during recent years, with an accompanying decline in annual rainfall. This is an important conclusion in relation to the analysis of declining groundwater levels (chapter 9).

Table 2.3 Basic statistics for rainfall stations in Sana'a Basin

Station	1st season mean mm	Cv	2nd season mean mm	Cv	annual mean mm	Cv	S1/ ann	S2/ ann
Sana'a airport 1974/93	120.8	.53	76.0	.80	196.9	.44	.63	.37
Sana'a Town, 1963-83	130.4	.58	134.9	.66	265.3	.44	.51	.49
Mind 1974/93	180.0	.45	128.1	.66	308.2	.34	.60	.40
Daba'at 1974/93	142.7	.37	110.7	.73	253.4	.36	.59	.41

The standard deviations (mean * Cv) of annual rainfall range between 34-44% and in 19 years out of 20, the annual amounts are between 50% and 150% of the mean. For comparison, in a temperate climate, the percentage for a similar period would vary between 75% to 125%. In more arid climates, the ratio of maximum to minimum annual amounts is much greater and the annual rainfall distribution becomes increasingly skewed. This can be seen in the Sana'a basin where the lowest standard deviation, 34%, is found at Mind, which has the highest annual mean, whereas the highest standard deviation of 44% occurs at the airport station with the lowest annual mean. The coefficient of variation of annual and seasonal point rainfall amounts is negatively correlated with the mean annual rainfall.

The annual rainfall proportion from the first rain season is higher than the second season for all stations, however for the town it is only slightly higher. The variability of the annual rainfall is less than the variability in either of the two season.

The wettest area is the south western part with mean annual rainfall of 308 mm, which is probably due to its geographic location and its altitude. The annual total rainfalls are given in Table 2.4 and is illustrated in Figure 2.4. In general, all four stations share the same wet, average and dry years.

Table 2.4 Annual Rainfall(mm)

Year	Airport	Mind	Daba'at	Town
1974	275	308	270	225
1975	379	525	422	379
1976	142	305	247	224
1977	336	498	447	440
1978	174	276	209	234
1979	95	224	169	119
1980	165	320	174	181
1981	167	375	353	307
1982	271	392	337	238
1983	333	510	324	246
1984	144	216	171	194
1985	155	299	186	201
1986	277	321	330	289
1987	118	207	226	169
1988	205	179	233	240
1989	116	203	180	167
1990	128	251	184	178
1991	72	186	104	123
1992	190	303	284	228
1993	196	265	219	235

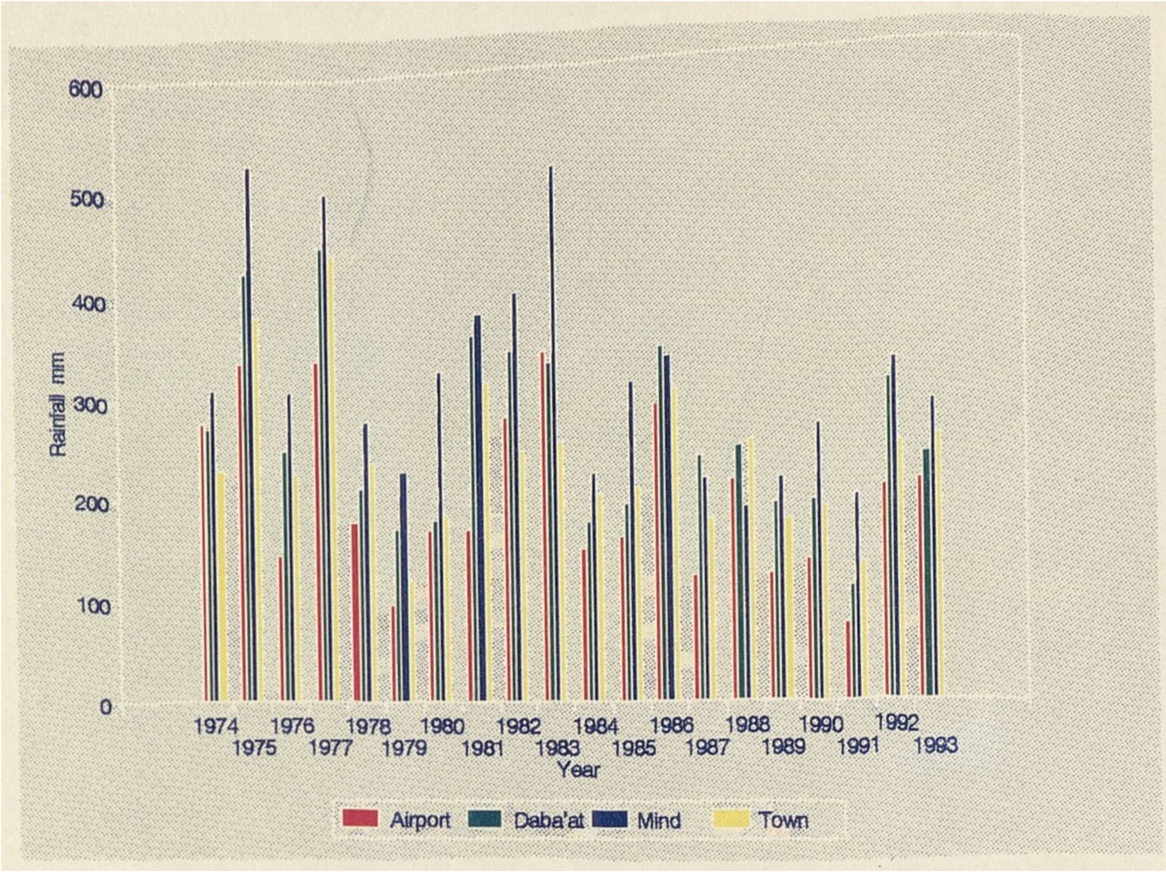


Figure 2.4 Total Annual rainfall (1974-1993)

There is only one raingauge in Sana'a with a long record going back to the 1930s, with a gap during the period 1948-1963. Italconsult (1973) attempted to estimate the missing data using data from weather stations in Taiz, Addis Ababa, Asmara and Wadi Jizan. Figure 2.5a shows the Sana'a annual totals. Assuming estimates by Italconsult were reliable, the statistical time-series analysis results showed a secular trend of a decrease in the annual rainfall by 3.45 mm per year. Although the annual time series show a greater degree of random inter-annual fluctuation, in general, the earlier period (1938-1953) was wetter than the average of all the recent years. Other wet years can be seen in the period between 1959-1964, however, there are less wet than the earlier period.

Using a 5 year moving average, which accentuates the oscillatory pattern suggested by the annual time series, it was found that although persistence is absent from the Sana'a annual rainfall time series, it is present in the series of 5-year moving means. This implies that estimates of long-term mean rainfall based on only 5 years of data range from 157 mm (1969) to 519 mm (1950) for Sana'a. In the period between 1940 and 1964, all years had rainfall above the average of 296 mm. The driest period was between 1968-1974, which is probably responsible for the decline of the groundwater level during early 1970s when there was no large scale abstraction.

By plotting the cumulative departures from the mean for the record period, the existence of a long term trend component in the Sana'a record was revealed, indicating a change in the mid 1960s from an increasing to a decreasing rainfall average (Figure 2.5b).

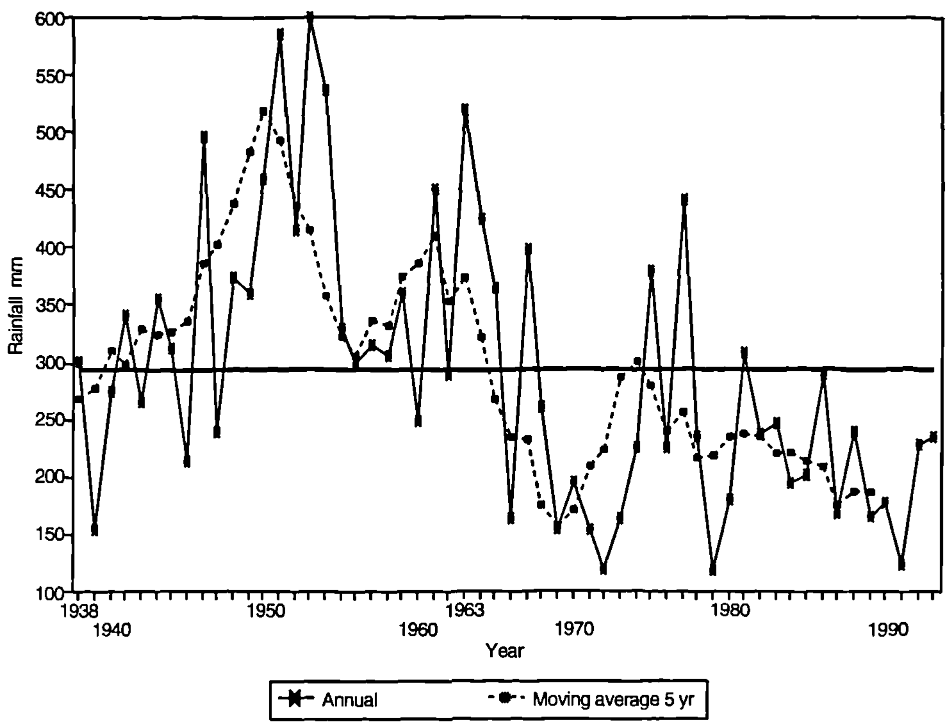


Figure 2.5a Annual Rainfall Sana'a Town, 1938-1992

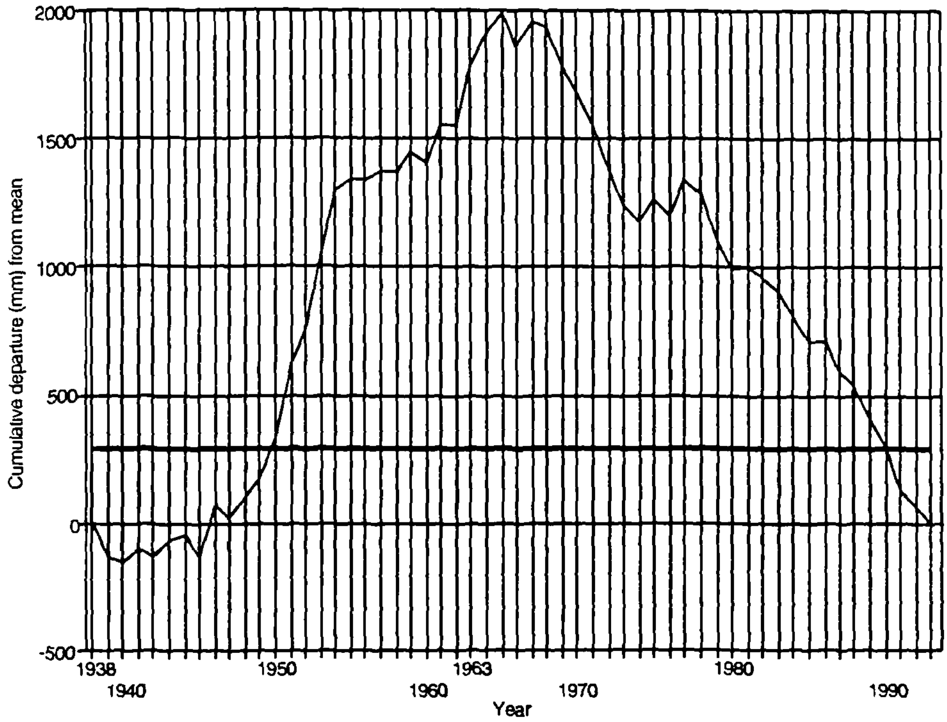


Figure 2.5b Cumulative departure from 1938 to 1993 mean (296 mm) for Sana'a Town weather station.

2.2.2.3 Monthly and Daily Rainfall

The average monthly rainfall distribution for the whole record (1974-1993) is illustrated in Figure 2.6 for four stations. The general climatic influences can be seen in the monthly distribution of the rainfall. Similarly to the spatial variation of the seasonal rainfall discussed above, the spatial variability within the basin can be indicated also from the monthly distribution of rainfall which varies from year to year at any station. For example, the monthly difference between Mind and Daba'at during March and May (first rainy season) is greater than that of July and August (second rainy season). Wettest months are March through May and July through August.

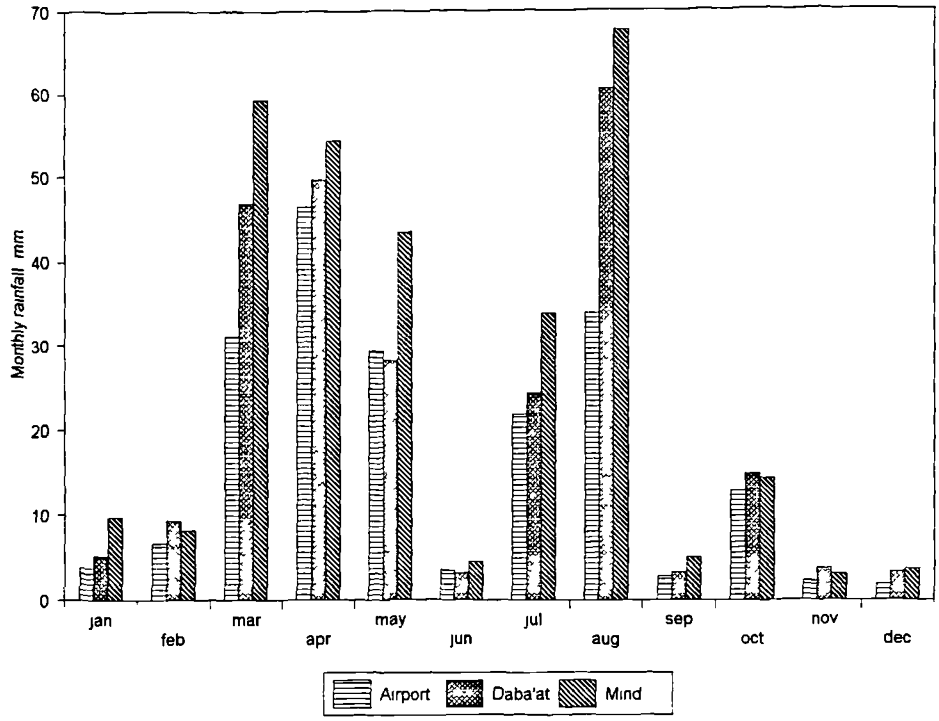


Figure 2.6 Average Monthly Rainfall Distribution

Daily rainfall data, unlike seasonal and annual rainfall, usually represents individual storm rainfall which might have a limited areal extent. The results of an attempt to use regression analysis to relate the daily data from the three weather stations, Airport, Mind and Daba'at, indicated poor correlation i.e very low coefficient of determination and high standard error of estimate. Increasing the time of span to 2 or 3 days would provide better correlation than the daily values. This is probably because lengthening the time scale results in the inclusion of more events and hence represents a summation of a number of individual events. If a shift in the rainy day by one or two days was allowed, strong correlations between the raingauge records would become evident. Using a spreadsheet program, the frequency of occurrence of daily rainfall for all records from the three stations were calculated, and presented in Table 2.5. A problem reported by TSHWC (1992) and FAO (1981) about the serious differences between stations in the precision of recording small daily rainfall, became evident from the unacceptable values for some statistical parameters. Similar to TSHWC, a rain-day has been defined as having at least 5 mm of rainfall.

Table 2.5 Frequency Analysis for Daily rainfall (1974-1992)

Name	Number of daily rainfalls in class (mm)									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	>45
Sana'a airport	7072	119	52	25	12	9	7	4	2	3
Mind	6958	158	74	48	20	14	11	3	10	9
Daba'at	7015	128	57	47	23	13	6	7	4	5

The spatial variation of the daily rainfall is important in the choice of rainfall series to be used as input to a rainfall-runoff model. An input of areal rainfall over the basin estimated from several rainfall stations has produced runoff estimates that are insufficiently variable. To avoid this, the basin has been divided into three rainfall zones; the first is represented by Mind raingauge and covers the south-western part, 397 km^2, including Wadi Dhar, Hamdan and Gabir. The Airport station was used over the second rainfall zone, which covers the central and north-eastern part of the basin, 1940.2 km^2, and includes Regions A, B and C. The third rainfall zone is represented by Daba'at raingauge, and covers an area of 871.7 km^2, which includes Wadis Hizyz, Akhwar, Gyman, Asfal, Alrawna, Rujam and Alsir (see Figure 2.2).

2.2.3 Other climatic parameters

2.2.3.1 Temperature

The monthly distribution of mean temperature is shown Figure 2.7a. The hottest month is July, with a mean monthly value of 22.5 °C and the coldest is December with 14.1 °C. The highest observed daily air temperature was 34.5 °C on 4/7/87 and lowest is -9.6 °C on 20/1/87, both recorded at AlIrra weather station. The air temperature during winter can fall below 0 °C. However this is related to which airstream dominates the area. The cold, dry, continental, northern wind lowers the temperature below zero, usually in the morning and lasts for few hours. But the comparatively moderate, humid, south-westerly wind brings warmer conditions. In both cases, the mid-day maximum stays high because of clear skies.

2.2.3.2 Humidity

Daily variation of air humidity is quite distinct with a maximum observed at night and minimum in the afternoon. The annual variation of air humidity tends to be similar to the distribution of the rainfall. The mean monthly relative humidity goes up to 51% in March and April, while during dry weather it drops to 35.8% (June) Figure 2.7b. The actual air humidity in rainy periods is about 12 mbar and the highest daily value about 16 mbar. In dry weather, the monthly average is about 7 mbar and daily values may fall to 3 mbar.

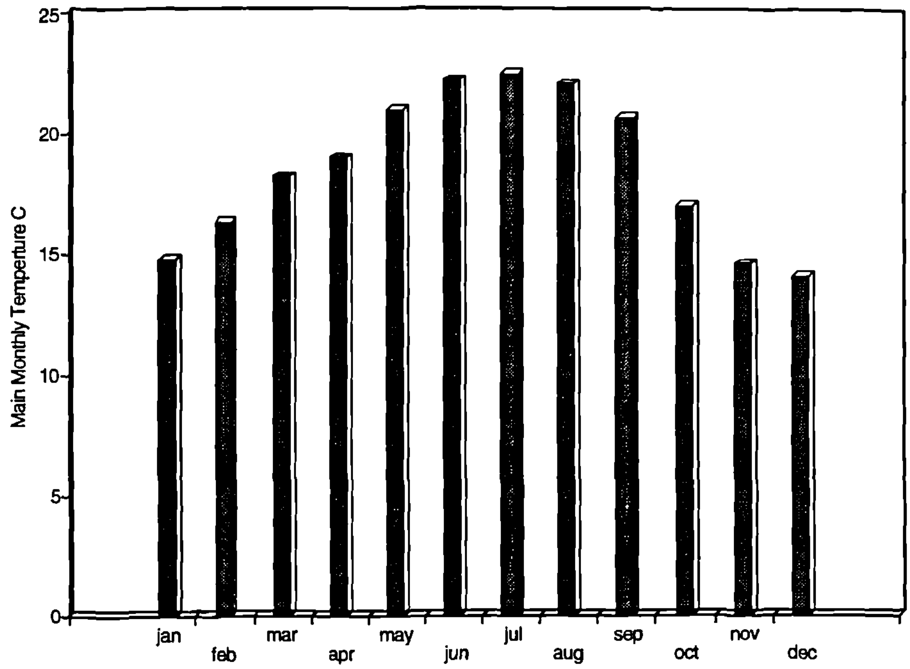


Figure 2.7a Monthly distribution of observed temperature

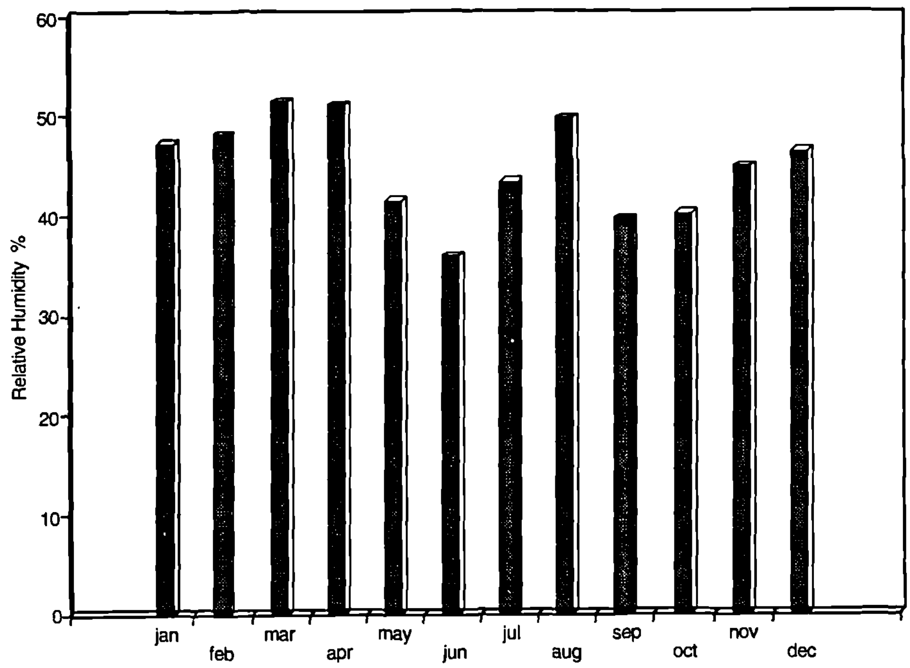


Figure 2.7b Monthly distribution of observed relative humidity

2.2.3.3 Wind speed

The mean monthly wind speed is small varying from 1.7 m/s in Nov. to 2.3 m/s in July. The highest daily mean recorded wind speed was 3.5 m/s and the lowest daily mean is 1.1 m/s.

2.2.3.4 Air pressure

Due to elevation of the Sana'a basin (2200-2800 m.a.s.l) the mean monthly air pressure varies between 787.5 mbar (November) and 783.6 mbar (July).

2.2.3.5 Sunshine

During summer, the sky which is usually clear in the morning, is covered by afternoon clouds which reflect and considerable weaken the sun radiation. The mean monthly observed sunshine hours varies between 7.4 hours in August to 9.7 in January.

2.3 Evapotranspiration

2.3.1 Introduction

In studying the water budget of an area, neither the reference nor the potential evapotranspiration provide sufficient information on the actual water output from a catchment by evaporation and transpiration. In semi-arid regions, since a significant part of precipitation or irrigation water evaporates back into the atmosphere, actual evapotranspiration is very important for the determination of the available groundwater in these areas.

The development of evapotranspiration is basically determined by the availability of water to be transformed into vapour and by the energy needed to change the phase of a given amount of liquid. The former is more important to determine the actual evapotranspiration from land, but the latter from free water surface. This also implies that in a humid climate the limiting factor for evaporation may be the available energy, whereas evapotranspiration is probably limited by the available water in arid regions.

Many formulae are proposed in the literature to calculate the expected value of evapotranspiration. Most of them are based on consideration of available energy by taking into account the radiation, the temperature, the deficit of moisture saturation of the air and the wind velocity. The most frequently applied formulae were given by Penman (1948) and by Thornthwaite, (Thornthwaite and Holzman, 1939) and Monteith (1965, 1981) for the Penman equation.

The evaluation of actual water loss from a vegetated land surface by evaporation plus transpiration adds further complexities to the processes involved in the evaporation from an open water surface. Several investigators (e.g. Brustaert, 1982; De Bruin, 1988; Shaw, 1990; and Lemeur and Zhang, 1990) agreed that the Penman-Monteith model successfully describes the transpiration and interception loss from different kinds of vegetation, such as tall, rough forest, arable crops, heathland and grassland. However, a crucial parameter in the equation is the canopy resistance, rc, which was evaluated from the measured evapotranspiration for three crops using water budget methods, then substituted in the Penman-Monteith equation. Estimation of rc from the actual evapotranspiration derived from the water budget method is described in section 2.3.3. The Penman-Monteith model and evaluation of its parameters are described in section 2.3.2. More discussion of the model and its parameters is described in Appendix A.

Due to the different types of soil, absence of vegetation, and infrequent floods in the wadi channel beds, the actual evaporation was estimated from the assumed relationship between the ratio of Ea/Ep (the actual/potential evaporation) and the soil moisture content. The rate at which actual evaporation falls below the level of potential evaporation as the soil moisture deficit increases is a controversial issue, and a number of models have been proposed. However, for the wadi channel, with bare soil, a relation between the accumulated evaporation and the square root of time has been reported (see Brutsaert, 1982). A simple exponential decline was used to estimate the actual evaporation as the soil moisture content falls below the field capacity. The potential evaporation, however, was estimated from the Penman-Monteith equation, with rc equal to zero.

2.3.2 Penman-Monteith Model

The Penman-Monteith model was used to estimate actual evapotranspiration for the three dominant crops in the basin for the period between 1986 and 1993, for which daily meteorological data were available.

The actual evapotranspiration rate is given by;

$$\lambda E = \frac{\Delta\ (Rn-G) + \rho a Cp/ra(es - ea)}{\Delta + \gamma(1+rc/ra)} \qquad (2.1)$$

Where

E rate of Evapotranspiration ($kg/m^2/s$) ($\equiv$ mm/s)

Δ rate of change of saturated vapour pressure with temperature (mb/°C)

Rn the net radiation (W/m^2)

G soil heat flux density (W/m^2)

ρa air density (Kg/m^3)

Cp specific heat of air at constant pressure (1005 J/Kg)

es saturated vapour pressure at screen temperature (mb)

ea screen vapour pressure (mb)

γ psychromatic constant

λ latent heat of vaporization (= 2465 KJ/Kg)

rc canopy or surface resistance s/m

ra aerodynamic resistance s/m,

Parameterization of various variables of the above equation (2.1) is described in details in Appendix A. However, a summary of evaluation of these parameter is given below under two terms which contribute to the evapotranspiration in the Penman-Monteith model; the aerodynamic term and the energy term.

2.3.2.1 Aerodynamic term parameterization

The aerodynamic resistance, ra for a specific surface roughness can be written as a function of the wind,

$$ra = \frac{[\ln (z-d/zo)]^2}{k^2 u} \qquad (2.2)$$

Where

k, is von Karman constant, experimentally found to be invariant with a commonly used value of 0.4.

zo, is the surface roughness length [L] for rough surfaces and its value is a function of the nature of the surface, that is the geometry, size and the arrangement of the roughness,

z, is the height above the ground (L)

d, is the zero-plane displacement height (L)

Typical values of z, ho, d and zo used in the calculation of the actual evapotranspiration in Sana'a basin for each crop are given in Table 2.6. Using values for each crop is important because using a gross average of roughness length for the whole basin may be inappropriate, as the effects of the short grass might be neglected by the dominating effects of tall grass.

Table 2.6 Typical values for ho, d, Z and Zo, used in the calculation of the actual evapotranspiration for different crops.

Surface condition	ho mm	d mm	Z mm	Zo mm
irrigated apples	8	5	100	1
irrigated grapes	450	300	1500	60
irrigated qat	750	500	2000	90

Using daily measured wind velocity in m/s, the daily aerodynamic resistance for each crop was calculated and the value was substituted in the Penman-Monteith equation.

Saturation vapour pressure, es, is the maximum moisture content the air can hold at a given air temperature. At this vapour pressure, the rates of evaporation and condensation are equal. Over a water surface, the saturation vapour pressure is related to the air temperature by the following approximate equation:

$$es = 6.11 \quad \exp\ (17.27\ T/237.3+T) \qquad (2.3)$$

where es in mbar and T is in degrees celsius.
By differentiating equation (2.3) the gradient Δ = des/dT (Clausius-Clapeyron equation) of the saturated vapour pressure curve is found by

$$\Delta = es/T\ (6790/T - 5.028) \qquad (2.4)$$

where T is the absolute temperature, and the constants come from equation proposed by Richards (1971), which compares well with Clausius-Clapeyron equation.

ea actual vapour pressure of the air, at a given temperature, has been calculated from the relative humidity (RH) through the relation (2.5), where data are not available;

$$ea = es * RH/100 \quad \text{mbar} \qquad (2.5)$$

The Psychometric (γ) constant is equal to

$$\gamma = Cp\ Kh\ P\ /\ .622\ L\ Kw \tag{2.6}$$

where the ratio Kh/Kw of the heat and vapour diffusivities is commonly taken to be unity (Priestley and Taylor, 1972), and P is barometric pressure in mbar L is the latent heat of vaporization and Cp is the air specific heat (=1005). By substituting the suitable values, equation (2.6) becomes;

$$\gamma = 6.5 * 10^{-4} * \quad P \qquad (\mathrm{mbar/K}) \tag{2.7}$$

2.3.2.2 Energy term parameterization

The energy budget equation may simply written as;

$$Rn - G = LE + H \tag{2.8}$$

Direct measurements of the net radiation are not available and hence it was broken into its components;

$$Rn = Rs\ (1-\alpha) + Rl \tag{2.9}$$

where Rs is (global) short wave radiation
α is albedo of the surface
Rl is the net long wave radiation
Then these components, if not measured as well, can be obtained by theoretical methods or simpler empirical formulae.

Global short-wave radiation, Rs, was calculated from the following formula;

$$Rs = (A + B\ n/N)Ra \qquad (2.10)$$

Where Ra is the extraterrestrial radiation, n is the measured actual sunshine hours and N is the maximum possible sunshine hours.
A and B are radiation constants taken to be .25 and .50 respectively, following the standard values used in the FAO methodology. Based on research done by Williams (1980) for the Montane Plains and Wadi Rima Project, different values of 0.33 and 0.44 were proposed for the constants in the Yemen highlands. By using the recorded data for sunshine (airport station)and radiation from AlIrra, a constant similar to that suggested by FAO has been obtained.

Typical values of surface albedo, α, used in the present study are given in Table 2.7.

Table 2.7 Albedo or reflection coefficients, (fraction)

Surface	albedo
Qat	0.25
grapes	0.25
Bare soil	0.20

No measurements are available in the Sana'a basin for the net long-wave radiation and it is obtained as a function of absolute temperature, actual vapour pressure and sunshine ratio.

Relative sunshine (n/N), is the actual number of hours of bright sunshine, n, and the number of daylight hours, N, which can be read from tables for a given latitude and month. Daily observed actual sunshine from Sana'a airport was used. For missing data, average mean monthly data has been used.

The net long wave radiation (W/m^2) was calculated in the present study from the following equation;

$$Rnl = \sigma/86400 * T^4 * (a - b\, ea^{1/2}) (f + (1-f)\, n/N) \qquad (2.11)$$

Where T is temperature, σ is Stefan-Boltzman constant (= $4.86*10^{-3}$ $J/d/m^2/k$), n/N is Relative sunshine, ea is actual vapour pressure (mbar), a and b are constants, of the equation to estimate atmospheric emissivity under a clear sky, to be determined from observational data. Values of 0.34 and 0.044 have been adopted from the values used by Rhebergen & van Waveren (1990) for the Yemen Highlands. The constant f, was used to allow the use of n/N as an approximation because no data on cloud cover are available and a value of 0.2 has been adopted from Brutsaert (1982).

The last parameter in the Penman-Monteith equation to be evaluated is the heat flux into the ground, (G) was obtained from relation;

$$G = C\, Rn \qquad (2.12)$$

where Rn is the net radiation and C is an empirical constant equal 0.3.

2.3.3 Estimation of actual evapotranspiration from water budget method

Methods of estimating actual evapotranspiration are based on the principle of conservation of mass applied to some part of the hydrological cycle. They estimate the actual evapotranspiration by using the explicit form of the water budget equation. The general equation expresses the equality between the difference of the input and outputs, and the change in water storage during the investigated period. It is generally assumed that all components but evaporation are measurable or negligible. Although from the conceptual point of view, these methods are by far the simplest, the use of this explicit form is influenced by many uncertainties, because all the measurements errors which occur in determination of other factors are combined in the actual evapotranspiration. These uncertainties are believed to be at a minimum when the equation is applied to a point measurement rather than a catchment.

The local evaporation was calculated using a one dimensional water balance equation; for a vertical soil column of unit cross sectional area, it can be written;

$$\int Ez\, dt = \int Pdt - \int q\, dt - \int (d\theta/dt)\, dz\, dt \qquad (2.13)$$

Where, Ez rate of evapotranspiration from the soil in a column of depth z (the sum of surface evaporation and root extraction, it varies with z through the root extraction), t is time in days, P is volumetric rate of addition of water to the column through precipitation, or irrigation, q is instantaneous rate of flow of water out from the bottom of the column, θ is volumetric water content and z is depth of the column considered.

When there is no input to the soil during the sampling period, (i.e P=0) evaporation rapidly lowers the moisture content and the pressure near the surface. A zero flux plane (defined as the depth where evaporation ceases and drainage occurs in the soil column, which corresponds to the maximum of the hydraulic head profile, (Vandervaere et al, 1994) develops, and moves downward over the time interval t1, t2. During this period, the first and the second terms in the right hand side of the soil water budget equation (2.13) become zero and the evaporation is simply equal to the change in total water content of all the soil in the column down to the depth of zero flux plane, ZFP. The location of this level, as a function of time can be determined from hydraulic head profiles measured by tensiometers.

This expression has been evaluated directly from plots of the measured soil moisture content versus depth at two specified times, and for three sites where ZFP was developed. Examples of these plots are illustrated in Figures 2.8 a, b, and c.

Also the magnitude of evapotranspiration between two consecutive dates, say t1 and t2, may be calculated if trapezoidal method applied to the following relation;

$$Et(t1,t2) = S(zo,t1) - S(zo,t2) \tag{2.14}$$

Where S is storage of moisture content.
However, this is more appropriate to small sampling interval depths, say 10 cm.

Table 2.8 Summary of the measured actual evapotranspiration by ZFP approach.

site	Dates	no of days	Total Et (mm)	Et/ day (mm)	Crop
Rawdha	10/8/93-24/8/93	14	47.3	3.4	Apple
Sawan	11/8/93-22/8/93	11	5.00	4.6	Grape
Bayt AlOzari	26/6/93- 6/7/93	10	31.2	3.2	Qat

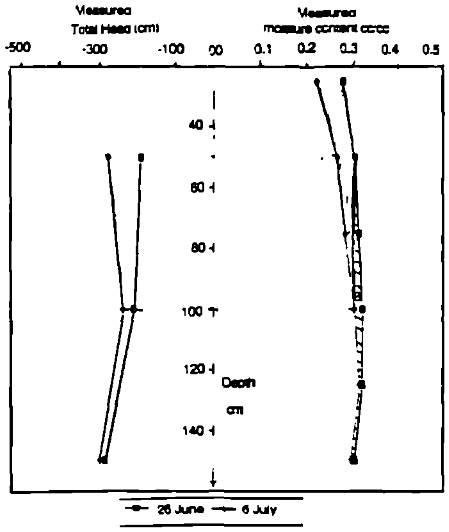
It is believed that with a careful procedure used in the field, and under favourable conditions (i.e. measurable soil water content and head pressure), reliable values of the local evapotranspiration at three sites were obtained. These values were used to calibrate the one dimensional model of vertical flow in the soil (chapter 4). Then the evapotranspiration, as computed from the numerical simulation (i.e for a longer period), has been used to evaluate the canopy resistance (rc) for each crop as shown in Table 2.9.

The evaluation of rc for each crop allows actual evapotranspiration to be computed using the Penman-Monteith equation for the main crops in the Sana'a basin over the last eight years. The detailed calculations are given in Appendix A.

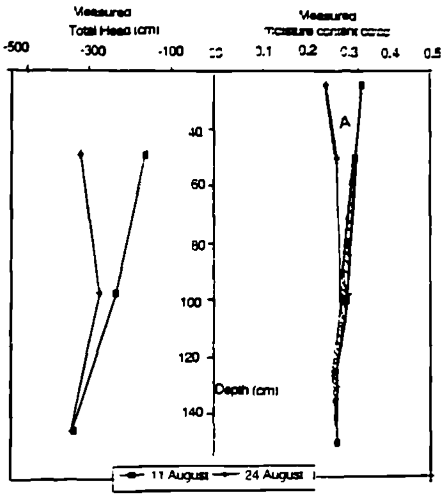
Table 2.9 Summary of the estimated canopy resistance (rc)

Qat		Grape		Bare	soil
Et mm/day	rc s/m	Et mm/day	rc s/m	Et mm/day	rc s/m
3.16	325	3.64	260	2.54	450

(a) Qat



(b) Apples



(C) Grapes

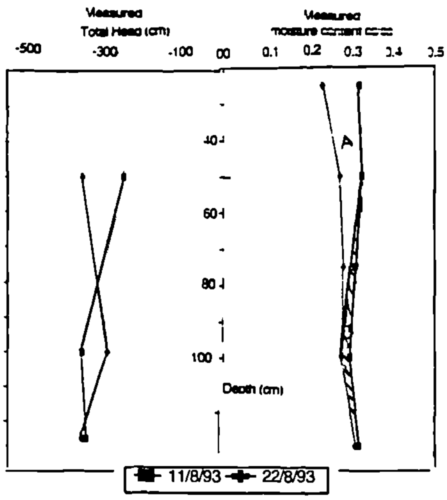


Figure 2.8 (A)evaporative, (B) flux of soil moisture profile, (a) Qat (b) Apples (C) Grapes.

The annual actual evapotranspiration for the three main irrigated crops in the Sana'a basin, as calculated by the Penman-Monteith equation are given in Table 2.10 for the period between 1986 and 1993 with daily meteorological data. These values are described and used to compute the irrigation return in Chapter 4.

Table 2.10 Actual evapotranspiration for three crops for the period between 1986-1993

year	ETc, Qat mm	ETc, grape mm	ETc, apples mm
1986	768	879	616
1987	763	878	625
1988	819	932	667
1989	763	873	625
1990	821	937	645
1991	807	881	656
1992	739	850	612
1993	772	878	629

3 GEOLOGY AND HYDROGEOLOGY

3.1 Background

The complex geologic setting of Yemen is the result of regional tectonic forces and events that controlled not only the deposition of sedimentary strata over geologic time, but also the character of the present day landscape in Yemen. These forces were also responsible for the complicated geological and hydrogeological conditions in the Sana'a basin. The geological evolution is described in section 3.2 and structural geology in section 3.4.

It is not possible to understand the groundwater hydrology of an area without having a clear and complete understanding of the geology. Rock type, stratigraphy and geological structure each play a key role in determining the occurrence, quantity, quality and movement of groundwater. The geology of the area is described in section 3.3. A description of the aquifer systems' geometry, hydraulic properties and groundwater occurrence is given in section 3.5

3.2 Geological evolution

The geological evolution of the Sana'a basin is described according to the stratigraphy presented in Table 3.1, the geological map in Fig 3.1 and geological cross sections in Figure 3.2.

Table 3.1 Generalized sequence of geological units in Sana'a basin.
(Compiled from Italconsult, 1973, Mosgiprovodkhoz, 1986 and Al-Anbaawi, 1985).

Yemen makes up part of the East African Pre-Cambrian shield. During the Early Palaeozoic Era, these rocks were levelled by erosion to a broad peneplain, then covered by sporadic continental deposits, which were eroded by the end of the Palaeozoic. Faulting then resulted in the formation of horsts and graben. The horsts were the sites of erosion and the graben were the basins of deposition. The Yemen-Harar horst is the source rock of the oldest sediments in the Sana'a basin. They were eroded, transported and deposited in alluvial plains and near shore environments. The continental sediments of the Kohlan formation may indicate a warm climate (AbuKhadra, 1982).

Further subsidence of the region followed, with the maximum true marine transgression over local depressions north of Sana'a during the middle and late Jurassic, forming a thick calcareous unit (Amran Group) under a neritic environment. A regression of the sea started by the end of Jurassic and a lagoonal stage occurred in the centre of the depressions, where shale, fine-grained sandstone and gypsum lenses were deposited (Wadi Alahjur formation), while the margin of the basin emerged and was subjected to erosion. The climate was still warm. A regression of the sea was completed during the Cretaceous and a continental sandstone and sandy conglomerate were laid down, (Tawilah Sandstone) probably over the entire area.

During the Palaeocene epoch, the continental conditions continued with the exception of the invasion of sea over the Sana'a basin, which resulted in the deposition of clastic, shallow marine sediments with some marine fauna, the Medj-zir formation (Geukens 1966). Italconsult (1973), from the lithology, suggested a continental environment. More recently, AlSubary (personal comm. 1992) showed restrictions of the marine fossils at certain layers within this formation. The presence of decomposed tuff and the soapy clay beds within this formation are a sign of the start of volcanic activity.

During the Oligocene Period, arching of the continental lithosphere of the East African shield took place, followed by the separation of the Arabian plate from the Nubian plate during Miocene times, with the formation of the rift valley of the Red Sea. Eruption of volcanics, along fault planes, during the arching and rifting stages resulted in the formation of stratified volcanics, which protected the underlying Mesozoic sediments from further erosion. Calm intervals during the Oligocene and Miocene produced fluvio-lacustrine deposits intercalated with the volcanics. Granite and granodiorite intrusion occurred during the late Tertiary, resulting in additional deformation and faulting of the surrounding country rock. Another phase of volcanism occurred during the Quaternary, forming basaltic volcanic cones, tuff layers and lava flows.

Block faulting related to the rifting processes has resulted in many NNE, SSW oriented faults. Two other major fault directions are NE-SE and NNW-ESE. The faulting formed grabens, which now constitute the intermontane plains are filled with unconsolidated Quaternary deposits.

3.3 Lithostratigraphic units

Figure 3.1 shows the outcrops of the main lithostratigraphic units in the Sana'a basin. A brief description for each unit is given below;

Amran Group, (Middle to Late Jurassic) covers 370 km^2 of the basin. It conformably overlies the Kohlan formation and is characterized by rapid lateral variation in facies; nevertheless, the calcareous nature is still the main characteristic feature of the Group. The Wadi Alahjur formation is equivalent to the Unnamed formation referred to by all the hydrogeological investigators after Italconsult (1973). It is generally marked by an angular unconformity with the overlying quartzitic sandstone of the Tawilah Sandstone. However, in very few places, the Wadi Alahjur formation grades upward into the quartzitic sandy conglomerate beds of the Tawilah sandstone without interruption. This is probably due to partial subsidence of the basin in places before the deposition of the Tawilah, which prevented the erosion and deposition of the calcareous basal conglomerates. The Amran group is disrupted by block faults and many of these faults as well as fissures and bedding planes, are filled with igneous intrusions. The Amran Group as reported by Howard Humphreys (1983) has a maximum thickness of 700-900 m.

Tawilah Sandstone, (Cretaceous) crops out to the north-west and north east of Sana'a city, over an area of about 180 km^2. It is represented by continental, cross-bedded and graded, stratified sandstone, with conglomeratic and argillaceous interbeds. The contact of the Tawilah sandstone with the overlying Medj-zir formation is generally marked by conformity.

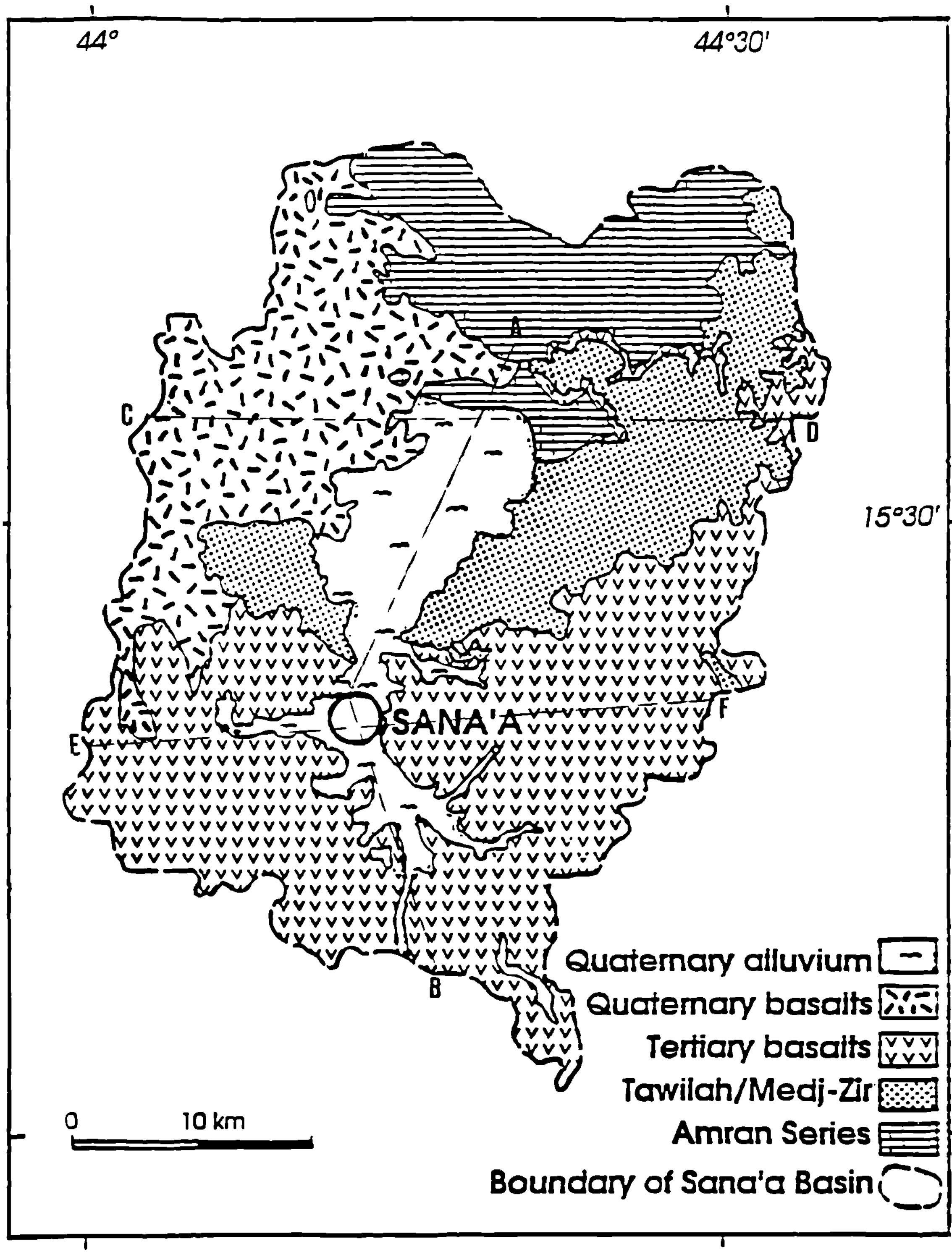


Figure 3.1 Geological Map of Sana'a Basin (after Mosgiprovodkhoz, 1986).

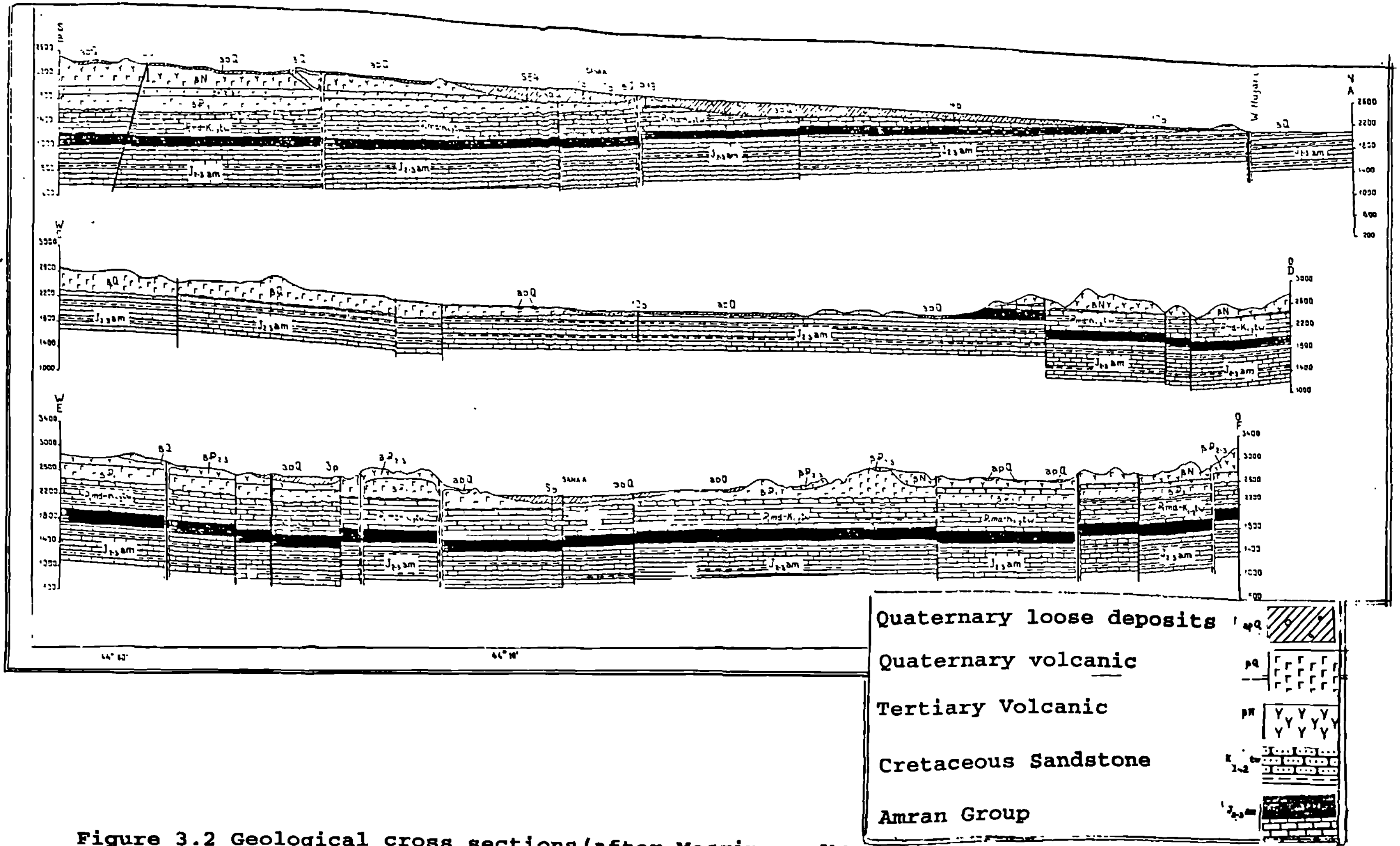


Figure 3.2 Geological cross sections(after Mosgiprovodkhoz, 1986)

The Tawilah Sandstone is partially eroded from the areas where the overlying Medj-zir was not deposited. In these cases, its upper part is generally immediately below the Tertiary or Quaternary volcanics. Italconsult (1973) examined this formation in outcrop in the Sana'a basin and also in nearby well, ST-4, to find the thickness reaches 350-400 m.

Medj-zir Formation, (Palaeocene) overlies the Tawilah, and it can be distinguished easily from the underlying Tawilah Sandstone because it is a slightly fossiliferous, finer grained, very hard, massive, compact ferruginous sandstone, with a high proportion of siltstone, clays and decomposed argillite. Its top is usually eroded or immediately underlying Tertiary or Quaternary volcanics.

Tertiary Volcanics, cover 1280 km^2, and can be subdivided into three units:

basal basalt, which consists of the first basalt lavas which covered the Palaeocene sediments. It is a homogeneous, greenish-black dense basalt, with columnar jointing. Small, scattered lenses of trachytic-rhyolitic material can also be found. This unit is intensively fractured and mineralogically composed of sodic alkaline feldspar, monoclinic pyroxene and quartz. It is exposed in the periphery of the Sana'a basin, on the slopes of the deeply-cut wadis, and has been encountered by some boreholes in the Sana'a plain at depths of 150 to 190 m. The thickness increases from 150-200 in north to more than 300 m in the south.

Stratoid rocks, which cover the basal basalt and are essentially pyroclastic, mainly of a rhyolitic nature. They occur as well-bedded tuff and ignimbrite, green, red and pink in colour, with gravelly sands and gravels of a fluvio-lacustrine type sometimes interbedded. The formation is about 100-200 m thick. It crops out in the lower part of the mountain slopes, where it has a thickness of 100 m. In the south of Sana'a plain, it occurs at a depth of 190 m and has a thickness of 120-200 m.

Chaotic and stratoid rocks, which consist of flows of basalt and rhyolite lavas chaotically intermingled, the former predominating. Above this horizon, bedded pyroclastic rocks resembling the first stratoid rocks are again to be found. This formation has a thickness of several hundred metres, (maximum of 500 m) with the top usually eroded. It is more widespread in the southern part of the basin, occurring only on the highest peaks in the more northerly parts. It includes rhyolite, trachyte, andesite, basalt and ankramite, besides a large variety of tuff.

Apart from the extensive formation of Tertiary volcanics, basic intrusive rocks are also present, represented by necks, dykes, and often intrusions of larger dimensions. Dykes are frequent, especially near the necks; these sub-vertical intrusions trend NNW-SSE and NNE-SSW and occur in tectonic fractures. They are composed mainly of basalt, but rocks of a decomposed tuff type are also found. The largest intrusion of granite occurs south east of Sana'a city and covers about 8 km^2 (Mosgiprovodkhoz, 1986).

Quaternary Basalt, occurs widely in the west and north western part of the Sana'a basin and covers an area of 600 km^2. It is made up of basalt, augite basalt, nepheline basalt, scoriaceous and vesicular basalt and basalt tuff, the latter found near eruption cones. They originate from various generations of basalt flows; some of these flows, especially in the WNW part of the area, are deeply incised by valleys whose origin is clearly fluvial. No erosion at all can be recognized on some flows and cones, particularly in the north-western part of the basin, and the innermost parts of the Sana'a basin. The thickness of Quaternary Basalt varies between 100 and 500 m. The only sediments which cover the Quaternary basalt are the loess-like silts. Generally, however there is no cover at all and the surface is rough and broken.

Quaternary loose deposits, are widespread and cover about 779 km^2 of the Sana'a basin. They are confined to wadi beds and low elevations forming the Sana'a plain. Their deposition has been controlled by the presence of block-faulted depressions and appears to have been fluvio-lacustrine in nature, which leads to the accumulation of silts and clays in small basins. Coarse grained colluvium and alluvium mainly occur in wadi beds and at the foot of hills. The coarse detrital material has been derived from the nearby bedrock.

3.4 Tectonics and Structures

Tectonic activity during the Red Sea rifting resulted in block-faulting with general directions NNE and SSE. Two other major fault directions are NE-SW and NNW-ESE and may have been a result of the opening of the Gulf of Aden. Regionally, the faulting formed horst and graben block structures, which exhibit displacements up to 2000 m. This faulting not only placed outcrops of various basement and sedimentary rocks at different elevations in each mountain range, but also created the regional topographic features in Yemen. These features formed under extensive conditions and acted as conduits through which magma poured, and erupted over the ground surface. However the degree of opening depended upon the stage of the volcanic activity.

The tectonic structure of the Sana'a basin is rather complicated, due to the number of faults which makes it impossible to map them all (Howard Humphreys, 1983). As a result of Mesozoic tectonic activity, development of a geosyncline was initiated, in which sediments were deposited. It is thought that the basin dipped southward with inclination of (3°-7°), as indicated from the Amran Group and the Cretaceous Sandstone. Other features have been marked by development of several large radius folds. The area of tectonic activity and extension of the earth's crust in the region resulted in a high degree of jointing of local hard rock. It is known that normal faults resulting from extension is hydrogeologically significant, as it usually results in fracturing of the rocks making them more permeable, whereas thrust faults resulting from compression, or those accompanied with volcanic intrusion, leads to development of a local metamorphic zone.

Dislocation along faults usually leads to a degree of alteration, the final product of this cataclasis is a fine-grained, often banded, rock called mylonite, made up of minute, angular grains enclosed in still finer dust-like base. These types of fault are more common in the southern part of Sana'a basin, and the largest one extends in an east-west direction. Geological logging of borehole 2P in this area revealed squeezed, mylonitized, welded basaltic tuff, with inter-layers of clay containing pyrite (Mosgiprovodkhoz, 1986).

A "groundwater of tectonic dislocations" as described by Mosgiprovodkhoz (1986), refers to water in the major fault systems, which stretch for tens of kilometres and lie hundreds of metres deep. They act as water catchment, conduits and outlets and they promote interaction between waters of various rock complexes (Alderwish, 1992). According to Mosgiprovodkhoz (1986), one such tectonic structure is a 4 km wide, abyssal fault dissecting the basin from north to south. Evidence cited in the study to support the significance of these structures was drawn from observations of high yielding wells and springs lying along its course. More recently, Alderwish (1992) confirmed this from the spatial variation of groundwater chemistry.

3.5 The Aquifer System

Groundwater occurs in several geologic units within the Sana'a basin,

- Quaternary sediments
- volcanic units (including Tertiary and Quaternary volcanic)
- Cretaceous sandstone (including Tawilah and Medj-zir formations)
- Amran Group

For each unit, the geometry of the water bearing unit is described, and the most likely hydraulic characteristics and a description of the piezometry are given.

3.5.1 Quaternary loose deposits aquifer

This aquifer is widely spread in the Sana'a plain where wadis debouch into it. It covers 25 % of the Sana'a basin. It consists of alternations of coarse-grained horizons (mainly silty sand and gravel) and very fine-grained horizons (mainly silty sand and silt).

The thickness of these fine horizons varies from 5 to 30 m and the thickness of the coarse sediment horizons from 5-20 to 60-70 m. The thickness of the Quaternary loose deposits varies considerably, reaching 300 m and more in the central part of the plain where it overlies the Cretaceous sandstone. To the south, it has thicknesses of 50 - 100 m and overlies the Tertiary basalt. A similar thickness has been reported on the northern part of the Sana'a plain, where the sediments overlie the Amran limestone. Figure 3.3 shows a simplified version of isopach map (Mosgiprovodkhoz, 1986), based on work of Italconsult (1973) as well as the Mosgiprovodkhoz survey. It shows small basins in the vicinity of Sana'a and in the plain, 8 km south of Sana'a, where these deposits overlie Tertiary volcanic. Two of these basins have thicknesses of about 100 m. The deepest basin is situated north of the city, where these deposits overlie the Cretaceous Sandstone with a maximum thickness of 300 m (near the airport), separating the eastern and western outcrops of the Cretaceous sandstone. A fourth basin exists in the north east of Sana'a and has a different orientation than the other three, whose orientation is mainly NNW - SSE.

The hydraulic parameters of the Quaternary deposits aquifer vary considerably depending on their fine-grained particle content. Italconsult (1973), and Howard Humphreys (1983) reported that these Quaternary deposits

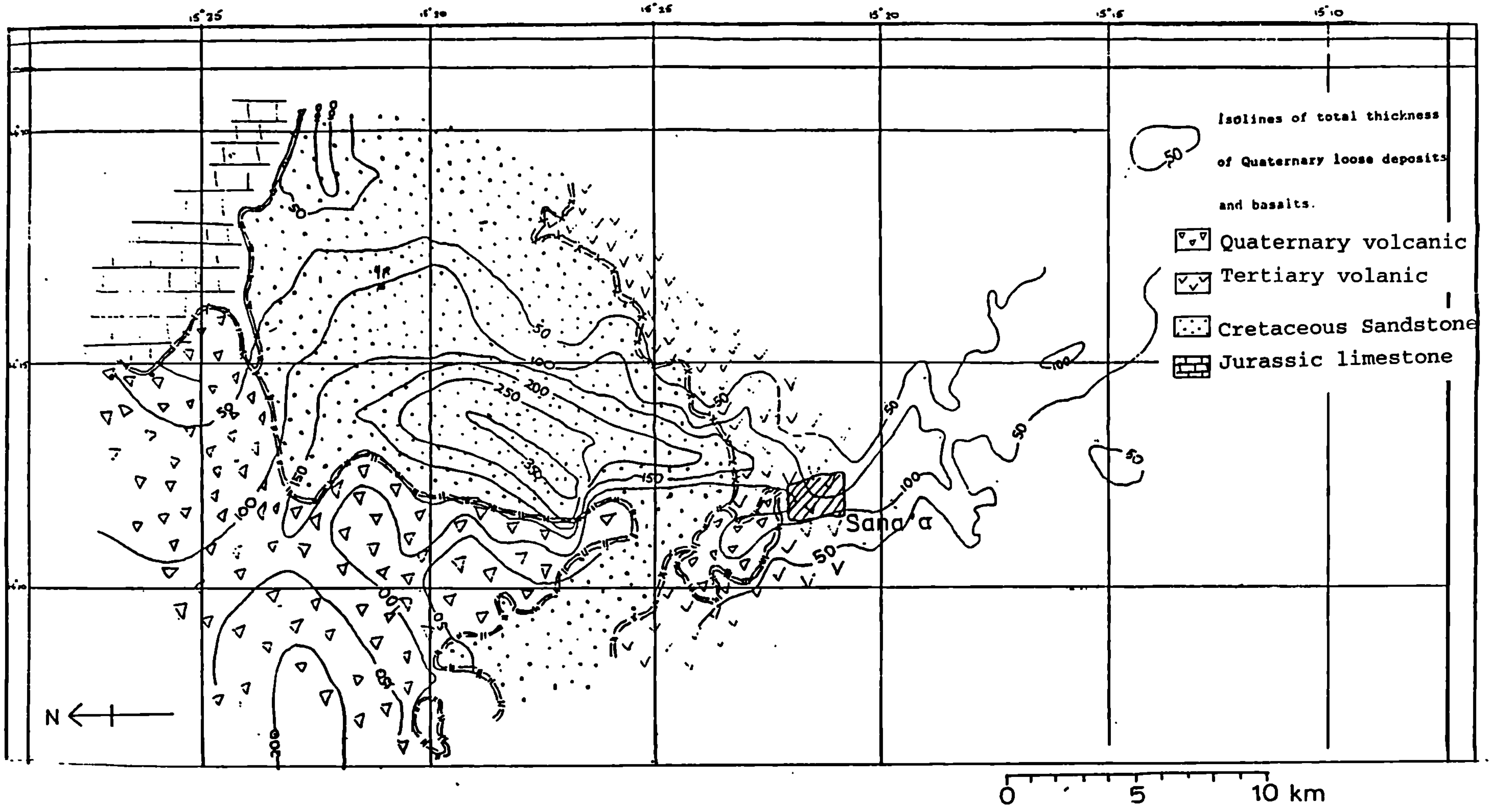


Figure 3.3 Isopach map for the Quaternary loose deposits (after Mosgiprovodkhoz, 1986)

of the Sana'a plain are generally considered to be a poor aquifer, and tend to have transmissivity values of the order of 100 m^2/day. The reported permeability is 0.9 m/day, which is indicative according to Freeze and Cherry (1979) of silty sand, moderate permeability aquifer material. Other values of permeability for each horizon within the aquifer were given by Mosgiprovodkhoz (1986). For the clean coarse-grained (gravelly) horizons within the aquifer, permeability varies between 10 to 35 m/d; for "dirty" coarse-grained horizons that are filled with silt and clay, it is 1.1 m/d, and for the sandy loam horizons, the value is 0.7 m/d. The suggested average transmissivity for this aquifer was 35 m^2/day (range between 3.6 to 82 m^2/d) (Mosgiprovodkhoz, 1986).

The porosity also varies, depending upon the material within the horizon. The porosity for the sandy gravel deposits vary between 11.6-24.7%, for sandy loam from 44 to 48%, and the average porosity for loams is 47%. The average specific yield was reported as 2% by Mosgiprovodkhoz (1986), whereas in southern part of the Sana'a plain it has been estimated from water balance and change in storage to be 1% by SAWAS team. Results from a pumping test in borehole in the south of the plain, SE-5 gave a storage coefficient of $4.1*10^{-4}$, which indicates semi-confined conditions, due to the fine-grained nature of the deposits (Italconsult, 1973).

The static water level in this aquifer occurs at a depth of 5 to about 50 m within primary wadis, shallower at the upstream end of the valley. In the Sana'a plain, however, its depth varies from about 55 m in the south to about 40 m within the city, and to 20 m north of alRawdha area, but increases again to 50 m at the northern border of the plain. The groundwater flow in this aquifer is generally northward along the major axis of Sana'a plain and in the down- stream direction in the wadis. However, it is thought that a groundwater divide has developed under the city, and the direction of water movement has changed towards the south of the plain (Blomaedaal, 1991). In the southern part of the plain, local variations of the water table gradient have developed and four cones of depression, which are related to high abstraction, have developed since 1972. A decline of 20 to 60 m in water level since 1972 within the south part of the plain has been reported by Blomaedaal (1990).

Within the city, steady state conditions prevailed during the period between 1983-1985, as a result of recycling of sewage water through cess-pits (Mosgiprovodkhoz, 1986). This is verified later in chapter 9, together with a description of the fluctuation in the water table of this aquifer during indirect recharge events through the wadis.

3.5.2 The Volcanic aquifers

3.5.2.1 Quaternary volcanic aquifer

In the north western plateau of the basin (Arhab), where this unit outcrops, its thickness decreases from 200 m in the south eastern part to 50 m in the eastern part (Figure 3.1). In this part, the unit consists mainly of fractured basalt, tuff and pyroclastic, interbedded with sand and sandy silt. This contrasts with the north- western part of the outcrop, where most of the unit is represented by dense, hard, basalt with a thickness of up to 300 m .

The hydraulic characteristics of the Quaternary basalt depend on both fracturing and the presence of clastic deposits between flows (i.e two types; intergranular and fracture permeability). Transmissivity of 180 m^2/d and specific capacity of 622 $m^3/d/m$ have been reported by Mosgiprovodkhoz (1986) in Hamdan area, in the south-east of the outcrop. Based on the hydrodynamic map and the report by Mosgiprovodkhoz (1986), an average transmissivity for the eastern and south-eastern part is 51 m^2/d and storage coefficient of 0.003, whereas in north-western part of the outcrops, the values are 1 m^2/d and 0.001, respectively.

Where the Quaternary basalt is saturated, it provides water-table conditions. The static water levels are deep, ranging from 61 to 138 m during 1983/1984, depending on the elevation of the ground surface. The groundwater flows to the east and north east toward Wadi AlKharid (Mosgiprovodkhoz, 1986). Italconsult (1973) considered the unit of importance to the recharge of the underlying formations, but Charalambous (1982) considered they were too thick to allow significant vertical infiltration. The former is more likely, as the basalts must be highly permeable since there are no springs, or other evidence of perched water tables, which would be expected if the basalt prevented the vertical flow of water. The high permeability was observed in an excavation during field work of the present study. Nash (1991) reported that the Russians report implied that the infiltration of surface flow after rain is rapid over this aquifer, however, it has been noticed that there is no water level monitoring data from this formation. Also Mosgiprovodkhoz (1986) estimated leakage from this aquifer to the underlying Amran limestone to be of 11000 m^3/day.

3.5.2.2 Tertiary Volcanic aquifer

Although geologically at least three formations can be distinguished within the unit (section 3.1), due to the limitations of hydraulic data, it has been treated as one water-bearing unit. The volcanic series occupies a vast area in the western, southern and eastern parts of the mountains framing the Sana'a plain. The thickness of the Tertiary volcanics is variable, reaching an estimated maximum of 700-900 m. It thickens markedly southwards to over 500 m at the southern boundary of Sana'a city (Midan alSabain).

The basalt flows and stratified sequence of this unit act as an aquiclude, except along fractured zones or within the entrapped sediments between basalt flows. Italconsult (1973) treated the basal basalt (lowest layer in the sequence) as an aquifer, with a low permeability of 0.5 m/d (200 m thick), whereas Mosgiprovodkhoz (1986) considered this unit as aquiclude. Both companies confirmed the presence of perched groundwater in the Tertiary volcanic hills south west of Sana'a, which exists in the more fractured part of the chaotic volcanics at the top of the sequence, and supplies the dug wells and high level springs above 2500 m.a.s.l. The contact between the basal basalt and Cretaceous Sandstone aquifer was examined by Italconsult (1973). They concluded that there is no real hydraulic boundary between these units and hydraulic interconnection was evident at Shamlan area (15 km NW of Sana'a city). Recently it was shown by Alderwish (1992) from hydrochemical evidence, that the interconnection between the two aquifers occurs through zones of high vertical transmissivity. Transmissivity of this hydrogeological unit varies between 200 m^2/day and 1 m^2/day. The highest values represent fractured zones along fault systems. An average transmissivity according to Mosgiprovodkhoz (1986) is 80 m^2/d, however, assigning one value may not be representative for a multilayer aquifer. Measured specific yield varies between 0.001 and 0.005.

Monitoring of groundwater level in the Tertiary volcanic unit started in 1972, but from only one borehole in the south of the plain (SE4). By the late 1970s, the number increased but commonly the wells penetrate more than one aquifer, either Quaternary deposits (e.g. A and SE4) or Cretaceous Sandstone (e.g B). Mosgiprovodkhoz (1986) monitored water levels in 12 wells tapping the volcanics between 1983 and 1985. Water levels from four boreholes within the city have been measured during the present study, and three in the south of Sana'a plain were measured by SAWAS since 1990, but the data from SAWAS are not available.

Occurrence of groundwater in the unit does not depend on the elevation of the ground surface but rather to the complicated structure of this multi-layered aquifer and hence is more related to the variation of permeability. As an example of the great variation in the groundwater table, data from three wells demonstrates the variation of the groundwater at wadi ASfal. The first well is 15.7 m deep, with static water level at 14.7 m. The second well is 5 m from the first one and it is 20 m deep and has water level at 18.1 m, i.e 3.4 m lower than that of the first well. The third lies 70 m away from the first two wells and has almost the same absolute elevation, but it was drilled in a fault zone of similar rocks down to 37.5, and has a water level of 36.8 m.

Although the static water level in the Tertiary volcanic shows great variability, the general trend of the groundwater is from the mountains towards the axial plane of the wadi and then downstream toward Sana'a plain, where it moves northward towards wadi AlKharid. In the fault zones, the groundwater flow direction depends upon the orientation of the fault. In places where the low permeability layer 'aquiclude' occurs close to the surface, there is perched groundwater. The spring Al-Balad in Wadi Dhar, which drains a perched aquifer along a major north-south fracture zone had a discharge of about 10 l/s during 1984. Hydrographs of wells observed by Mosgiprovodkhoz (1986) showed the highest levels of the water table were during May/June and in August/September. The lowest levels occurred during March/April. The response is rapid, up to 1 month following the rainfall event.

3.5.3 Cretaceous Sandstone aquifer

As it is difficult to distinguished the Tawilah sandstone from the Medj-zir formation, both in aerial photographs and drill cuttings (Italconsult, 1973 and Howard Humphreys, 1983), both were mapped together as one unit, and the term Cretaceous Sandstone includes both formations (Nash, 1991).

The aquifer outcrops mainly in the north eastern and north western part of Sana'a city and sinks rapidly below the surface toward the south of the Sana'a plain, probably in a step-faulted manner. At the southern limit of Sana'a city, it occurs at 630 m below surface according to the deep borehole of SAWAS.

The permeability of the Cretaceous Sandstone is characterized by both primary (intergranular) and secondary (fractures) permeability. The abundance of the fine-grained sediments and the cement material in this unit, decreases the significance of the intergranular permeability; the secondary permeability is due to fractures of variable density, depending upon whether they result from dislocation alone (fault) or with volcanic intrusions (e.g. dykes). Although geophysical logging indicated fracturing throughout the sequence, calculated transmissivity values from pumping do not increase with increased penetration of aquifer (Howard Humphreys, 1983), as became apparent when some shallow existing well were deepened in 1988. This implies that the fractures are tighter at depth (Nash, 1991). The variation of the distribution of fractures has led to variation in the transmissivity of the Cretaceous Sandstone aquifer; the highest values ranges are 400-2000 m^2/d (Mosgiprovodkhoz, 1986) and the lowest is 10 m^2/d which is related to an unfractured location (Howard Humphreys, 1983). Where the aquifer outcrops or occurs beneath up to 50 m of unconsolidated cover, the aquifer is mainly under unconfined conditions, with an average specific yield of 5% (range 1%-20%),(Charalmbous, 1982, Howard Humphreys, 1983 and Mosgiprovodkhoz, 1986). The aquifer becomes semi-confined or confined when it is covered by other formations, particularly the Tertiary volcanics with storage coefficients ranging from $5*10^{-3}$ to $5*10^{-4}$. Confined conditions are also found in deeper part of the aquifer where the aquifer is separated by sills intruded along stratigraphic planes or shale/silt layers within the Cretaceous Sandstone.

The Cretaceous Sandstone is the only aquifer with an adequate water level monitoring network in the wellfield areas. Depth to water level in this aquifer depends upon the topography and the rate of abstraction. According to Mosgiprovodkhoz (1986), in areas of low abstraction, it varies from 25 to 30 m in the lower lying areas, to more than 150-280 m on the highland of the plateaux surrounding the Sana'a plain. In areas of high abstraction, as a result of the development of cone of depression, the water levels exist at depths of 40 to 130 m. Generally due to intensive exploitation of this aquifer, the water table is gradually declining. Data from the 1970's, however, indicate that water levels were declining before pumping started for the city supply or for large scale irrigation. The rate of water level decline in the western well field varies from one borehole to another; various estimates of average rate were reported, the highest rates of decline have been shown by Howard Humphreys (1980) to be due to interference between pumping wells. Mosgiprovodkhoz (1986), observed one well in this aquifer located at the mouth of Wadi Alsir during 1984/1985, which shows rise during late September/ early October of 0.34 m, whereas the minimum water table occurred in March.

3.5.4 Amran Group aquifer

The Amran Group comprises limestone, marls and shaly limestone. The Amran crops out in the north of the basin, covering about 12 % of the total surface area. It occurs at depth in the Sana'a plain. At the airport, the top of Amran is approximately 350 m deep, at AlRawadha 500 m, and further south near Sana'a 900 m or more. The topmost part of the Amran is composed of lagoonal shales, fine grained sandstone and marls interbedded with lignite, known as the Wadi Alahjur formation. This formation is equivalent to the "Unnamed formation of Italconsult", which represents the transitional sequence between the Amran and Tawilah Sandstone. In this study, it is discussed within the Amran limestone, rather than as a separate formation, because it is belongs geologically to the Amran Group and has been insufficiently studied so far.

The Amran Group is generally a poor aquifer with significant permeability along fracture zones only. It shows a wide range of transmissivity, from 10 m^2/d to 104 m^2/d. Results of permeability tests for the AlKharid dam show a very low intergranular permeability of about 0.3 m/d. The fracture permeability is common in beds with fine-grained dense limestone and varies between 5 m/d to

22 m/d. Thus the formation is practically impermeable except along fault zones. Reported storage varies between $1*10^{-3}$ and $2*10^{-4}$

The depth to water table is over 100 to 130 m in the plateau area in the north west of the outcrop. In the north east along valleys leading to wadi AlKharid, the depth to water is less than 35 m and groundwater is extracted mainly by dug wells.

4 RECHARGE FROM IRRIGATION

4.1 Introduction

Despite the limitations of the water resources in the Sana'a basin, agriculture uses 77% of the total abstracted groundwater. No study has been conducted to estimate the proportion the water applied for irrigation that escapes evapotranspiration and passes back to the aquifer. The only comprehensive detailed study on agricultural resources development in the basin was done by the Russians (Mosgiprovodkhoz, 1986). However they do not report any percentage of the irrigation water return (Nash, 1991).

Irrigation schemes are frequently a major source of recharge to aquifers, whether they use groundwater or surface water (Lerner et al, 1982) particularly in arid regions. Losses from irrigation, which are potential recharge, occur in two areas; canals and fields. Field losses vary with the type of irrigation: flooded paddy, intermittently flooded field, furrow or spray irrigation. Canal losses in the Sana'a Basin are considered to be insignificant because of the limited extent within farms and they are not carrying water at all times.

Recharge by deep percolation from irrigated fields has many similarities to recharge by precipitation and the same methods may often be used to estimate them. For example, soil moisture budgeting methods can not always be applied for precipitation alone in arid and semi-arid climates, but they are more likely to be valid when there is a regular supply of irrigation water.

A numerical modelling approach based on the Darcy equation and field data is equally applicable to irrigated fields, and can give more accurate results because of the more regular conditions. Data requirements are soil moisture, soil water potential measurements and soil hydraulic properties (i.e K-P-W relationship). Soil moisture content and suction pressure were measured during the growing season of 1993, and have been used to estimate the soil hydraulic properties using a computer code called SOIL and by solving flow problem. The measurement techniques are described first, then a detailed description of the procedure developed to estimate the soil hydraulic properties is given. The daily meteorological data and amount of irrigated water applied have been incorporated with the other data to simulate the soil water movement. Finally the regionalization of the point measurements is described in section 4.5.

The measurement of soil moisture and soil water potential data have other uses, for example estimating actual evapotranspiration (chapter 2).

The soil has been classified (Mosgiprovodkhoz, 1986) into two main types; "mountain embryonic rock outcrops" (soil group 1), which covers an area of 1149 km^2 (36.8%) of the basin, and "mountain grey-cinnamon undeveloped soil type" (of light and ordinary subtypes), which covers the rest of the area (63.2%). The latter has further been divided into six groups; four of them with irrigated land. Table 4.1 describes briefly these soil groups. Sites for field measurements were selected in the last five soil groups (i.e. 3, 4ir, 5ir, 6ir, 7ir) and the location of the measurements are shown in Figure 4.1

Table 4.1 A summary of the soil types present at Sana'a Basin (after Mosgiprovodkhoz, 1986)

soil group	area km^2	present study sites	description
1	1149	-	mainly rock outcrops
2	896	-	light carbonate under-mature eroded *sand loamy, with stones and fine rock debris*, light and medium loamy soils
3	83	Faculty of Agriculture	light carbonate slightly eroded sporadically slightly solonetzic and slightly saline, *sandy loamy and light loamy soils with stones and fine rock debris.* (slightly gravelly sandy mud)
4	241		light carbonate cultivated slightly, eroded predominantly, slightly solonetzic, sporadically slightly saline, *light and medium loamy,rarely sandy loamy soils.*
4ir	25	alRawdha	irrigated,(sandy loam- loam)
5	438		light carbonate, agricultural, *light and medium loamy, rarely sandy loamy soils.*
5ir	10	Sawan	irrigated,(loam)
6	58		light carbonate solonetzic, agricultural with signs of compactness, medium and occasionally *heavy loamy soils*
6ir	35	AlOzari	irrigated,(loam-silt loam)
7	179		ordinary carbonate, agricultural sporadically slightly saline, slightly solonetzic with signs of compactness *light and medium loamy rarely heavy loam and clayey soils.*
7ir	5	Tabri	irrigated, (silt loam- silty clay)

* ir refer to irrigated soil.

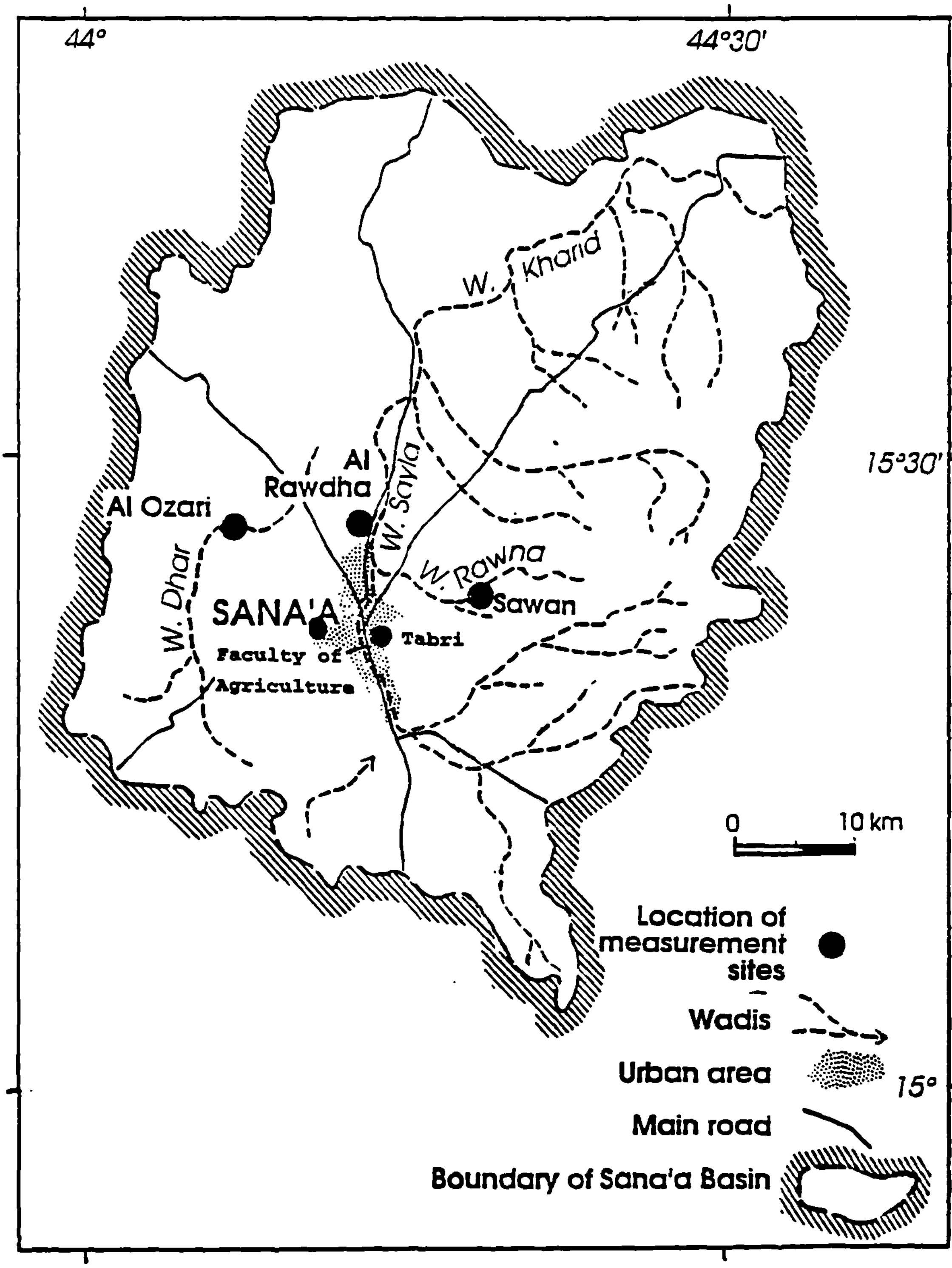


Figure 4.1 Location of measurements sites

4.2 Measuring techniques

4.2.1 Soil water content

Among methods available to estimate the moisture content of the soil, the use of a neutron probe is a common technique that allows rapid evaluation of soil water conditions at exactly the same locations over a period of time.

The neutron probe is a source of fast or high energy neutrons and a detector of slow or thermal neutrons. The fast neutrons are slowed down by collisions with the nucleus of matter in the soil and then absorbed by the soil matter. Since the mass of the nucleus of hydrogen is the same as that of a free neutron, the presence of hydrogen will result in a high field of thermal neutrons.

Although the resulting thermal neutron flux will show how much hydrogen is present (i.e water), a number of factors both creating and absorbing thermal neutrons may affect the results obtained. One factor is the size of the effective measurement sphere of the probe itself. Drier soils contain fewer hydrogen atoms, which provide neutron thermalization and back scatter resulting in a large sphere of measurement. Where boundaries occur within a profile between wet and dry soil, the neutron probe will indicate an "averaged" moisture content, θ, that is not representative of either soil layer (McHenry, 1962). This leads to difficulties in interpretation of abrupt soil moisture changes with the neutron probe. In particular, wetting fronts, water tables and textural changes (Greacen and Schrale, 1976) can not be interpreted precisely. Although dugwells may complement the neutron probe data by reading the water level depths, this was attempted but proved unhelpful because the water table is relatively deep, varying between 10 m at Dhar and 42 m in Sana'a city.

In addition to the inter-layer effect induced by moisture content boundaries in the soil, the predictive ability of the neutron probe for moisture content is also affected (Sorenson et al, 1989) by soil bulk density iron content and salinity. Of these factors, soil bulk density and texture play the most significant role in the accuracy of soil water measurements in the Sana'a basin.

From the above, it is clear that the neutron probe can be used as a measuring device for moisture in the soil and allows rapid evaluation of soil water conditions at exactly the same locations over a period of time, but requires calibration for local soil conditions.

4 ~~2~~.2.2 Calibration of Neutron probe

A manual soil auger bit of the same diameter as the access tube was used to make 8 holes, with depths of 1.8 and 2.4 m. The auger was lengthened to 2.5 m at the Faculty of Agriculture workshop, by fixing an adjustable rod. While digging the hole to install the access tube, a volume sampler of smaller diameter than the tube (5 cm) was used to take core samples (98.175 cc) at 25 cm intervals. This has the advantage that the calibration is performed on the tube to be used for readings. The volume samples were sealed by their plastic covers immediately after removal from the soil. The samples were weighed wet and dry (dried for 24 hours at 105 °C in a vented oven). Volumetric moisture content was calculated using the formula (Hillel, 1982):

$$\theta = V_w / V_t \qquad (4.1)$$

$$\rho = M_s/V_t = M_s / (V_a + V_w + V_s) \tag{4.2}$$

$$\theta = W \rho/\rho_w \tag{4.3}$$

where

θ moisture content

V_w volumetric water content

V_t total volume of sample

V_a Volume of voids

V_s Volume of soil particles

W Mass wetness (gravimetric water content= M_w/M_s)

M_s Mass of dry soil

M_w Mass of water

ρ dry bulk density

ρ_w water density

Equations (4.1) and (4.3) should give the same value for the volumetric moisture content. By assuming the density of water equal to unity, the volumetric water content will be equal to the weight of water divided by the total volume of the sample.

The relation between volumetric soil water content and neutron counts was developed for each site by a simple linear regression on a hand calculator using the measured data. The relation has the form;

$$M = A\ (Cr) + B \tag{4.4}$$

where M is volumetric moisture content, Cr is count ratio, A and B are regression coefficients. Table 4.2 gives the developed equations together with the coefficient of determination and standard error of estimates of the moisture content for the three sites. The detailed data are given in Appendix B.

Table 4.2 Regression equations for Count Ratio and Moisture content

Sites	The equation	r^2	SEE
AlOzari	M = 4.27E-5 Cr -.12438	.79	.029
Sawan	M = 6.58E-5 Cr -.28146	.95	.010
AlRawdha	M = 1.1E-4 Cr -.7071	.97	.005

The relationship between the counting rate and water content is approximately linear, as commercial instruments are usually designed to approach a linear calibration as closely as the basic processes of slowing down and scattering will permit. To check the work of the neutron probe, two readings at the same depth while the probe was lowered and raised in the hole were taken. An example is given in Table 4.3, which shows an error of less than 2%.

Table 4.3 Readings of Neutron probe at Bayt AlOzari

Depth (cm)	Downward (counts)	Upward (counts)	Difference	%error
25	6565	6579	-14	0.20
50	7462	7416	46	0.62
75	8389	8243	146	1.70
100	9078	8960	118	1.30
125	9225	9279	58	0.59
150	9401	9385	16	0.17

The measurements were carried out at five sites. Each site represents a different soil type (Mosgiprovodkhoz, 1986), has a different crop and is located at different part of the basin, east, west, north and central, so representing the whole basin.

Moreover, the crops selected represent major irrigated crops in the basin (grapes and qat). In two sites, two access tubes were fixed, so spatial variability could be shown.

Reading intervals need to be appropriate to the particular study and can vary with the rate of change of soil moisture. Where changes are slow, two weekly intervals are sufficient. The measurements in the Sana'a basin were carried out using a 10 day interval with $\pm$ 4 days. This was convenient (transport) and sufficiently accurate for the study.

For each access tube, information defining the crop, field measurements, calibration of neutron probe and moisture content profile are given in Appendix B.

4.2.3 Soil Matric Potential, Ψ

Understanding of the principles and techniques used in this report requires a clear definition of several basic terms and concepts commonly used in the literature of soil physics. Definition of these terms, is made within the text.

The matric pressure is the potential that arises from the interaction of water with the matrix of solid particles in which it is embedded. Its value is expressed as a pressure relative to atmospheric pressure. At the water-table, the matric pressure is zero and above the water table it is negative, (also known as suction force or tension). A soil Ψ of - 20 KPa is greater than a soil Ψ of -100 kPa. Soil Ψ is one component of total water potential Ψ_w defined as follows (Baver et al 1972)

$$\Psi w = \Psi m + \Psi g + \Psi p + \Psi b \tag{4.5}$$

where Ψw is total water potential
Ψm is soil matric potential,
Ψg is gravitational potential,
Ψp is pressure potential, and
Ψb is osmotic potential.

Matric potential is derived from two components, capillary and adsorptive. Capillary forces result from the surface tension of water and its contact angle with the particle (Hillel, 1982). Adsorptive forces result from the hydrogen bonding of polar water molecules with the oxygen atoms on soil particle surfaces. Water is adsorbed onto particle surfaces in layers. The first few molecular layers are held very strongly to particle surfaces by the adsorptive forces. Each succeeding layer is less strongly held . The relative importance of the two types of forces that make up soil matric depends on the amount of particle surface area, soil structure and the soil water content (Hillel, 1982). The capillary effect tends to predominate in sandy soils, which may have surface areas of less than 1 m^2/g of soil. The adsorptive forces predominate in finer textured soils with high percentages of clay, which may have a surface area of over a hundred square metres per gram. In these soils, there is little void space that is not occupied by adsorbed water, and thus soil structure is usually insignificant in determining matric potential of the soil. Regardless of the type of soil, when soil matric potential is less than about -30 KPa, enough water has been removed from the soil so that adsorptive forces predominate to the extent that capillary forces can be virtually ignored.

A tensiometer is a device which measures the soil water potential and consists of a tube filled with water and connected at the end to a ceramic cup, which is in close contact with the soil and allows water to move freely through the walls between the soil and the water-filled systems of the tensiometer (in response to the pressure difference), but excludes air when wet. However, as the suction increases towards 1 bar (100 KPa), air comes out of solution and the water column in the tensiometer breaks. The negative pressure or suction of the water is measured by a vacuum gauge connected at the upper part of the tube.

The time of response of the tensiometer to a change of matric potential is determined by two characteristics of its construction, the conductivity of the porous ceramic cup and the sensitivity of its pressure measuring device. The tensiometer response equation is first given by Richards (1949);

$$P = P_1 - (P_1 - Po) \exp -(KSt) \qquad (4.6)$$

where Po is initial water pressure inside the tensiometer body at the time zero, P_1 is the pressure maintained in the soil outside the tensiometer for $t>=0$. At sufficiently large time t, the pressure inside the tensiometer body will approach P_1. The parameter 1/(Ks) is the time constant ,τ, of the tensiometer. So for a good response, τ should be as small as possible.

The measurements of matric pressure were carried out simultaneously with the moisture content, by inserting the tensiometer into samples taken at depths of 50, 100, and 150 cm. Although tensiometers are commonly fixed in the field, this was not possible because only three tensiometers were available and they might have been vandalized if they had left in the field.

It is worth noting that, although samples were taken from the field using an auger, it is believed that the measurement of the suction still valid. This is because the suction has been measured once for each sample. Suction pressure was also measured for a few samples collected by digging out blocks of soil; by comparing these with suction matric measured for auger samples, the results broadly agree with findings in the literature, Marshall and Holmes (1979), and Hillel (1982). The measured suction pressures, given in Appendix B, are however less frequent than moisture content measurements, due to the difficulty of digging and insufficient availability of tensiometers. Matric potentials have also been determined from the relation with more measurable neutron-probe data (water content). Once a moisture characteristic curve has been defined for each site, it can be used as a calibration curve for determining the missing matric potential values from water content, but, because of hysteresis in this relationship, its use for this purpose is greatly restricted (Marshall and Holmes, 1979). The derived matric potentials, were used to obtain initial estimates of evaporation (ZFP) which were used in the numerical simulation.

4.3 Soil hydraulic properties estimate

4.3.1 Analytical models

The amount of water remaining in the soil at equilibrium is a function of the sizes and volumes of the water-filled pores and hence it is a function of the matric suction. This function is usually measured experimentally using an undisturbed soil sample and it is represented graphically by a curve known as soil moisture characteristic. Another function required to define the soil hydraulic properties is the unsaturated hydraulic conductivity relationship (K), which is expressed as $K(\theta)$ or as $K(h)$ depending upon whether it is considered in relation to the soil moisture (θ) or to the hydraulic pressure (h). While the relation between $K(\theta)$ and θ is physically more meaningful, the relation between $K(h)$ and h is more useful in flow analysis where, $K(h)$ is to be adjusted to the hydraulic head (h) as determined from elevation and depth from the reference level (Bouwer, 1974, 1978). The relation between $K(h)$ and h is governed by pore configurations and can also be experimentally determined for each particular material.

Although the unsaturated hydraulic properties $\theta(h)$ and $K(h)$ are strongly nonlinear functions of the pressure head, to proceed with analysis, it is assumed that suitable analytical expressions for these functions are available. Strictly, the problem is one of the model identification as well as parameter estimation since the correct functional forms of $\theta(h)$ and $K(h)$ are generally unknown.

Frequently used expressions for the hydraulic functions are those developed by Brooks and Corey(1964),

$$Se = (hp/h)^{\lambda} \quad \text{for } h > hp \quad (4.7)$$

$$Se = 1 \quad \text{for } h < hp \quad (4.8)$$

where hp and λ are fitting parameters, determined by plotting log Se against h.

and Van Genuchten, 1978, 1980,

$$Se = 1/\left(1 + |a\,h|^{n}\right)^{m} \quad \text{for } h <= 0 \quad (4.9)$$

$$Se = 1 \quad \text{for } h >= 0 \quad (4.10)$$

in which a, n, and m are fitting parameters, and m is related to n by (m = 1 - 1/n)

Vacluin et al, 1979

$$Se = \frac{b}{b + [\ln h]^{c}} \quad \text{for } h <= -1 \text{ cm} \quad (4.11)$$

$$Se = 1 \quad \text{for } h >= -1 \text{ cm} \quad (4.12)$$

Where b [in units of $(\ln \text{cm})^{c}$] and c are fitting parameters.

Brutsaert, 1966

$$Se = \frac{A}{A + h^{B}} \quad \text{for } h < 0 \quad (4.13)$$

$$Se = 1 \quad \text{for } h > 0 \quad (4.14)$$

in which A and B are fitting parameters.

Se is the effective saturation defined as $(\theta-\theta r)/(\theta s - \theta r)$ and θs and θr are saturated and residual water contents, respectively.

These equations as written here are valid for monotonic water i.e wetting or drying only. When the flow process involves both wetting and drying, hysteresis in the differential (or specific) water capacity C(h) will have to be taken into account.

Parameters required to define the shape of the soil characteristic curve, using one of the four expressions, were determined from the weighted arithmetic mean of measured Ks, θs and θr for each soil type, (Table 4.4, Mosgiprovodkhoz, 1986) and by estimating the remaining parameters by fitting these functions to the measured (θ,h) using the tensiometer and neutron probe data. The fitting was made using the computer program SOIL (El-Kadi, 1987), which uses a nonlinear least-squares analysis to estimate the curve shape parameters for any of the four hydraulic functions. This allows comparison between the performance of different functional forms and thus selection of the most appropriate model for each soil. It was found that van Genuchten's expression $(\theta-h)$ has the minimum residual error with all soil types, but that the Brooks and Corey model produced a better correlation for the relative conductivity function $(K-\theta)$. This agrees with other work by Kool et al (1987), van Genuchten and Neilsen (1985) and El-Kadi (1989).

Table 4.4 Summary of measured soil properties (compiled from Mosgiprovodkhoz, 1986)

Soil Group	Measurements site	plot numbers Mos.(1986)	θs	θr	Ks* m/d
3	Faculty of Agriculture	4,12,14	.42	.13	-
4ir	AlRawdha	28, 29	.47	.09	.115
5ir	Sawan	2, 6, 11	.434	.103	.048
6ir	AlOzari	8, 15, 17	.431	.142	.072
7ir	Tabri	24	.365	.095	.04

*ks is saturated hydraulic conductivity for the least permeable layer within the column.

The problem of estimating parameters for a specified analytical expression for a soil becomes simple as can be seen from the steps of the procedure;

(1) Enter measured values θ and h (minimum 10 observations).
(2) The program requires values for saturated moisture content θs, saturated hydraulic conductivity Ks and residual moisture content θr. However there is an option within the program to estimate the last two, Ks and θr.
(3) Select one of the four expressions available
(4) Note the residual between the data and the curve. (or SEE, the standard error of the estimate).
(5) Repeat (3) with different expression and (4)
(6) Select the expression which provide the least residual error

The SOIL program use series-parallel model of Childs and Collis-George (1950) to estimate the unsaturated hydraulic conductivity function. It assumes a linear relationship between relative hydraulic conductivity and effective saturation to be a straight line on a log-log paper, with N as the average slope. Using the results, a regression equation between unsaturated hydraulic conductivity and moisture content was developed for each soil type with simple form;

$$K = c\ \theta^{b} \tag{4.15}$$

Where
K is unsaturated hydraulic conductivity
θ soil moisture content
c and b are regression coefficient.

This relationship is required by the CHEMFLO computer program used in the simulation of soil water movements. Details of the SOIL model for $h(\theta)$ and $K(\theta)$ as well as a description of the nonlinear least-square analysis can be found in El-Kadi (1984).

In general, the disadvantages of such an approach are the time-consuming data collection and the fact that parameters are fitted to (θ,h) data only, so that any inaccuracy in the assumed hydraulic relationships, as well as effects of measurement error are forced into the predicted $K(\theta)$ (Parker et al ,1985). Figure 4.2 illustrates the moisture characteristic curve together with relative conductivity function as has been drawn by SOIL computer program for soil 6ir at AlOzari. Curves for the other two soil types, 4ir(AlRawdha) and 5ir(Sawan), are given in Appendix B. The estimated parameters for these soils and the standard error of estimates are given in Table 4.5a.

The measured data from the access tube at Faculty of Agriculture were found to be of poor quality. The selection of this site was not successful because, at the start of the onion growing season, the crop was stolen, so the farm supervisor stopped irrigation.

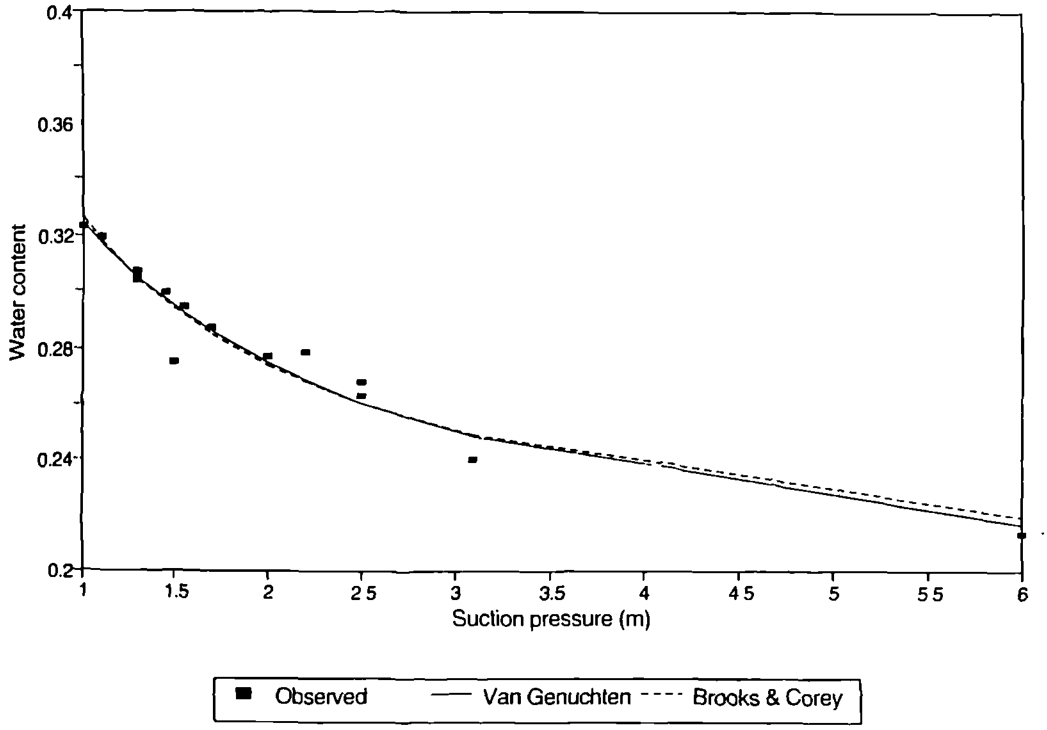
For Tabri site, the constant b in equation (4.15) is larger than 10, which is not accepted by CHEMFLO.

Table 4.5a Estimated Parameters from SOIL from van Genuchten's function of the moisture characteristic curve and the relative hydraulic conductivity of Brooks and Corey.

Soil group	a	n	SEE a	SEE n	ksat (m/d)	N*
4ir	.02222	1.342	.00430	.0339	.115	7.6
5ir	.00572	2.116	.00079	.2888	.048	5.2
6ir	.01863	1.558	.00234	.0518	.072	5.2

*Assuming relationship of the relative hydraulic conductivity and the effective saturation to be a straight line in a log-log paper, N is the average slope.

The model-derived site characteristics curves are representative of the average characteristics of the entire profile, and thus may not predict soil characteristics precisely at all depths. However, as the application here is to estimate the return flow from irrigation, the saturated hydraulic conductivity of the least permeable layer within the profile has the predominant effect (Rushton, 1988) and hence the least measured Ks in the soil profile has been used.



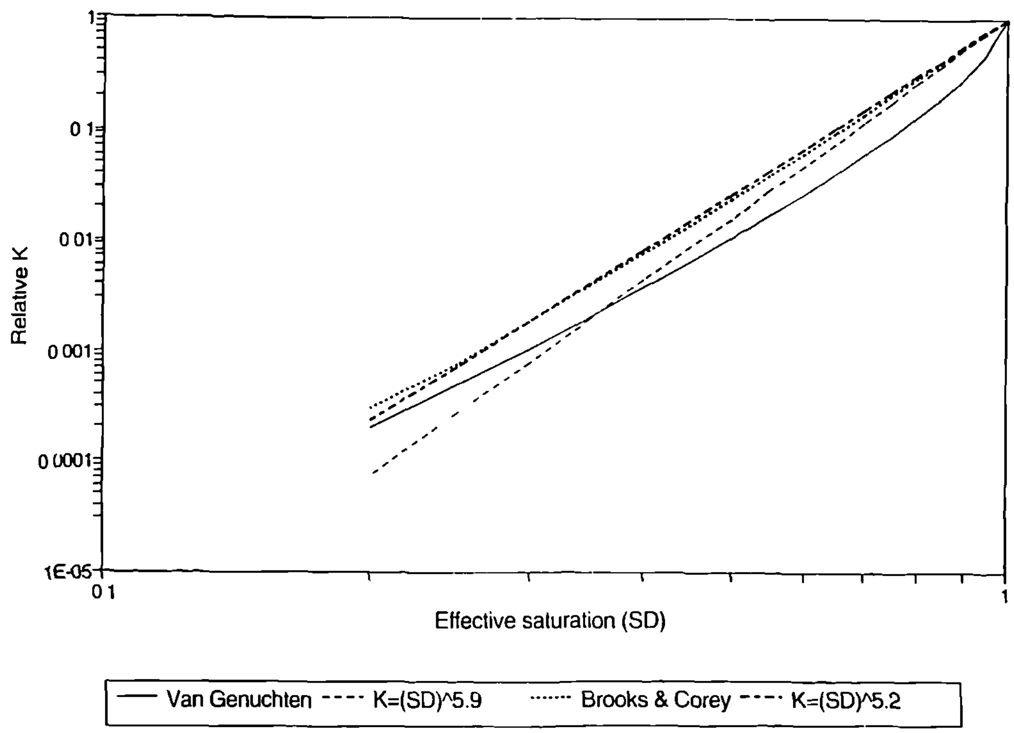


Figure 4.2 Soil moisture characteristic curve and Relative conductivity function for irrigated silty loam (6ir) at Al Ozari.

4.3.2 Numerical Flow Model

Due to the heterogeneity of the soil profile and uncertainty in the choice of analytical expression, the curve fitting method produced a range of possible values of the shape parameters defining the hydraulic properties. The uncertainty has been reduced by simulating flow in the soil profile and refining the hydraulic properties to obtain a good calibration between observed and simulated moisture profiles.

Estimation of hydraulic properties from transient flow measurements, by numerical inversion of the partial differential equation for one dimensional unsaturated flow has been tried by a number of authors, (Zachmann et al 1981, 1982, Dane and Hruska, 1983). This method uses Richard's equation, (Richards, 1931);

$$C\,(h)\;dh/dt = d/dx\;[\;K(h)\;(dh+z)/dx\;] \tag{4.16}$$

where x is distance; t is time; K(h) is the hydraulic conductivity as a function of the pressure head h; C(h) is the soil water capacity, being the slope $d\theta/dh$ of the soil moisture characteristic curve $\theta(h)$, where θ is the volumetric water content; and z is the gravitational head such that dz/dx = zero for horizontal flow, +1 for vertical flow with x positive upwards and -1 for vertical flow with x positive downwards.

Analysis of vertical moisture flux in an isotropic soil was simulated using a one dimensional numerical model CHEMFLO (Nofziger et al, 1989). It uses an implicit finite difference solution of a linearised form of the Richards equation (4.16). The software contains an algorithm to determine the initial mesh size in time and depth, however, the user has the option of entering other values as well. The additional computation made by the CHEMFLO is the cumulative flux at the boundaries. The model assumes isotropic soil, and it does not incorporate a sink term within the equation, that might represent for example extraction from the root zone. In reality, evaporation from the surface of the soil can cease after a while, however vegetation continues its activity and transpires water extracted from the soil by their roots. To allow for this transpiration from below the surface, CHEMFLO used a higher driving force at the surface to fulfil the imposed flux rate at the upper boundary. This was observed only at one site (Dhar), and only in the top 25 cm of the simulated profile, because there was no regular irrigation "water supply" which keeps the surface wet like the other sites. Moreover as the depth of measurements is greater than the sod, no effect was observed.

Parameter estimation of this type has been done in laboratory experiments, but at comparatively few field scale experiments. Although determination of in-situ properties is more relevant than data obtained from laboratory analyses when the results relate to field scale processes (Kool et al 1987), both approaches have their limitation, and field experiments involve in situ measurements of water content and pressure heads during transient flow. Moreover solution of the flow problem (equation 4.16) requires the stipulation of suitable initial and boundary conditions.

Initial conditions were taken as the measured water content profile and pressure profile. A constant evaporation rate measured during periods without surface input provided an upper boundary condition, while a fixed head condition at the lower boundary was determined by the tensiometer reading at a depth of 150 cm.

During the same period, in the lower part of the column below the zero flux plane (ZFP), the evapotranspiration and rainfall/irrigation are zero. Replacing vzdt by vz(t2-t1), where vz is the average moisture flux for the period, and solving the simplified water balance equation (similar to equation 2.13) for vz, the following equation is obtained;

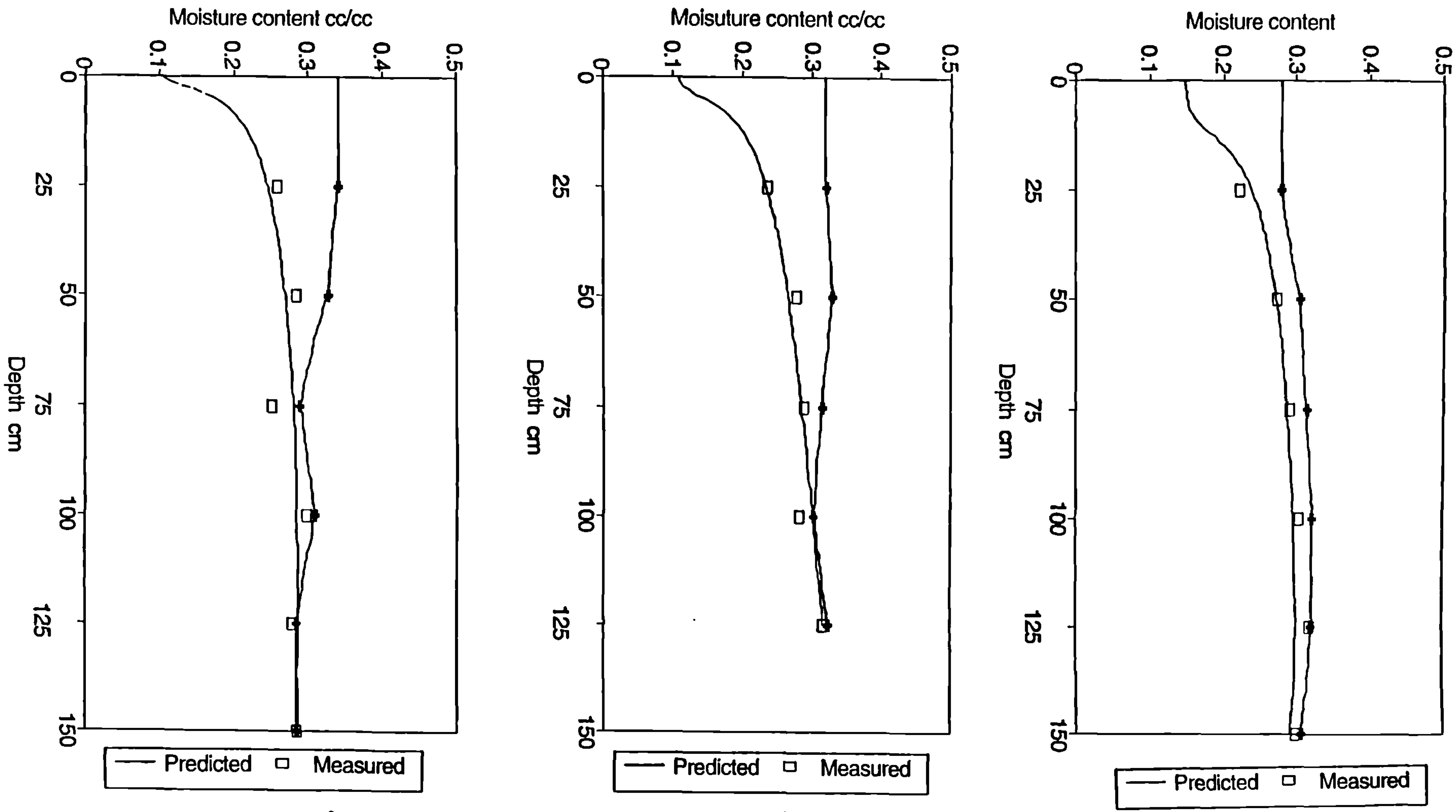
$$vz = 1/(t2-t1) \iint (d\theta/dt)\ dz\ dt \tag{4.17}$$

Thus the average moisture flow from the lower part of the profile during the period is calculated from the moisture content-depth profiles generated by the measurements. These flux values were divided by measured values of hydraulic gradient to obtain values of $K(\theta)$ corresponding to various average values of θ. This is the usual method to measure the $K(\theta)$ relation in the field, however, the upper zero flux plane is usually created by covering the ground surface. In the present case, the ZFP was moving downward and, as this movement is not known exactly, the results were indicative and further supported the initial estimate used for the more accurate relation, obtained through numerical simulation of the vertical flux of water in the whole column, adjusted by trial and error, to minimise the difference between the measured and predicted water content.

In summary, the method involves: (1) Selecting a period with a known evaporation rate. (i.e with Zero flux plane developed), (2) Using an initial estimate of soil hydraulic properties, obtained from SOIL model, (3) Running the model for the specified period, (4) Comparing results; if unsatisfactory, changing the parameters in the K-θ relation and rerun the program until agreement is reached. An example of this methodology is given for soil type (6ir). Figure (4.3c) shows water content profile at the initial condition (26/6/93, 2 days after irrigation) at Bayt alOzari. This profile was subjected to a constant evaporation rate of 3.15 mm/day, at the surface, while at a depth of 150 cm, the lower boundary, the pressure was held constant at -145 cm, because the change in the actual pressure was not significant during the sampling interval. By changing the parameters in the $K(\theta)$ relation, a good agreement was obtained between the measured and predicted water content profile of 6 July, as shown in Figure 4.3c. The same approach was used for two other sites and the results are shown in Figure 4.3a for soil 4ir at AlRawdha and Figure 4.3b for soil 5ir at Sawan. The results from the above improvement for hydraulic soil properties are shown in Table 4.5b.

Table 4.5b The model derived soil hydraulic parameters (eq 4.9) and (eq 4.15) for three soil types.

Soil group	a	n	Ksat m/d	c	b
4ir	.01720	1.339	.115	1551.1	10.65
5ir	.00599	1.967	.048	140.5	7.85
6ir	.01647	1.606	.072	3146.8	11.00



(a) Soil 4ir

(b) Soil 5ir

(c) Soil 6ir

Figure 4.3 Verification of K-θ through model calibration,

4.4 Numerical Simulation of Return flow

Once model-derived soil hydraulic properties for each soil type were determined and evaluated, they were used to calculate the volume and time distribution of return flow, when there is an input of rain or irrigation water to the soil. For these calculations the CHEMFLO model was applied to each of the three sites for a period of four months. The duration of the longest time steps was 1 day, but very much shorter steps were used when there were rapid changes in water application and evaporation at the surface, the upper boundary of the model. Initial conditions were based on the earliest measured moisture profile at each site. The lower boundary at a depth of 1.5 m was defined by the sequence of suction pressures measured by tensiometer. The flow domain was divided into a grid of 150 nodes, each with a uniform thickness of 10 mm. The choice of a fine mesh and short time steps minimised the numerical errors in the solution technique. For each site, the results were verified by comparing the sequence of measured and simulated soil moisture profiles, and the return flow was derived from the cumulative flux passing the lower boundary.

The contrast in soil types, crops and irrigation practices at the three sites allowed testing of this method for a variety of conditions, as well as calculation of irrigation return for the three most extensive irrigated crops in the Sana'a basin.

4.4.1 Return flow from irrigated apples

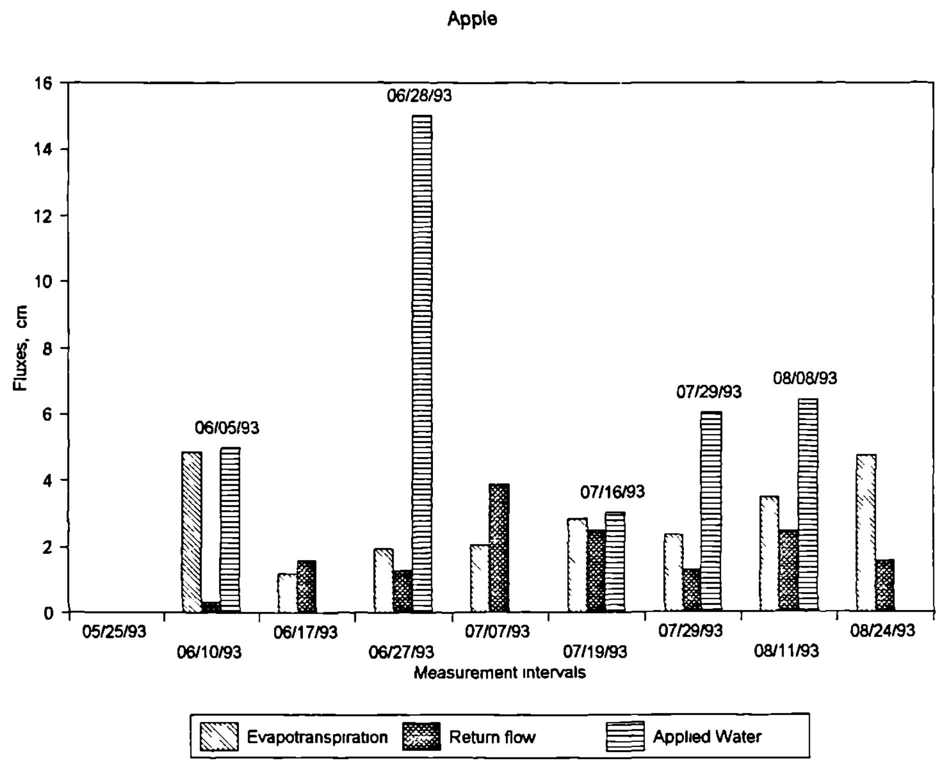
The measurement site at AlRawdha is located between two trees, in a field of apple trees spaced about 1.5 m apart, and may thus be more representative of bare soil

(Plate 4.1). This was confirmed by the low evapotranspiration rates, ranging from 2.1 mm to 3 mm/d. The measurements from a coarse soil layer at a depth of 0.75 m were always inconsistent with the numerical simulation and were not used for calibration. This site was irrigated more frequently than the other two, with four applications of 50, 150, 30, 60 mm on 5 June, 28 June, 16 July and 29 July 1993. Also it received total rainfall of 64 mm during August, as shown in Figure 4.4. The total amount of infiltration, 148 mm, represents 42% of the total water, 290 mm, applied between 20 May and 25 August, indicating a much lower irrigation efficiency (short experience (6-7 years) of the Yemeni farmers for planting apples) than the other sites and faster infiltration in the coarser sandy loam soil. As a result, the soil moisture also varied more rapidly, especially close to the surface as illustrated by Figure 4.5.

Table 4.6 Summary of CHEMFLO Results at AlRawdha

Date	Days of time interval	Soil water flux across upper boundary cm	Soil water flux across lower boundary cm
25.5.93			
10.6.93	16	4.8620	0.3490
17.6.93	7	1.1928	1.5791
27.6.93	10	1.9200	1.2957
07.7.93	10	2.0520	3.8780
19.7.93	12	2.8300	2.4669
29.7.93	10	2.3400	1.2766
11.8.93	13	3.4260	2.4552
25/8/93	14	4.7000	1.5381
Total	92	23.3228	14.8407

(a)



(b)

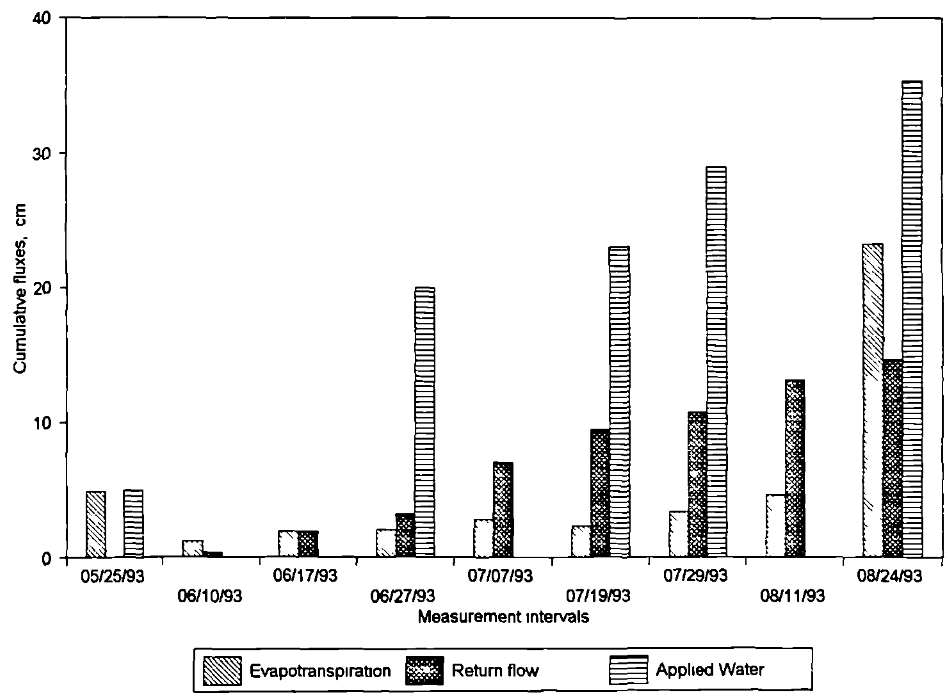
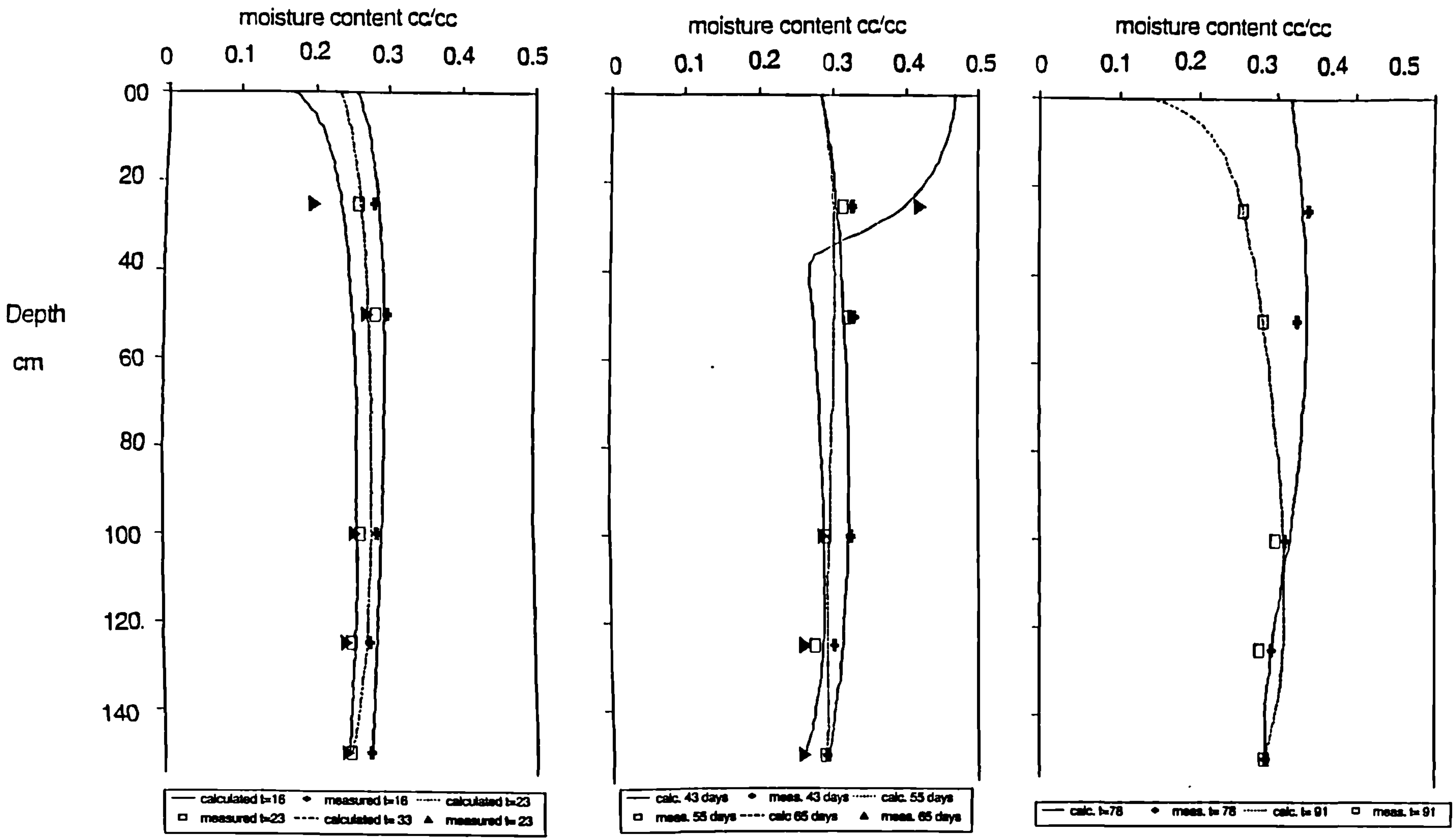


Figure 4.4 Graphical presentation of; (a) Fluxes at upper and lower boundaries of soil 4ir column (b) Cumulative fluxes.



moisture content cc/cc
0 0.1 0.2 0.3 0.4 0.5
Depth
cm
00 20 40 60 80 100 120. 140
calculated t=16 measured t=16 calculated t=23
measured t=23 calculated t= 33 measured t= 23
calc. 43 days meas. 43 days calc. 55 days
meas. 55 days calc 65 days meas. 65 days
calc. t=78 meas. t= 78 calc. t= 91 meas. t= 91

Plate 4.1 Space between apple trees, access tube and neutron probe, at Al Rawdha site.

Plate 4.2 bunds and collected rainwater in irrigated field at Sawan.

4.4.2 Return flow from irrigated grapes

Figure 4.6, shows the measured and predicted soil moisture profiles over the period of the investigation at Sawan site, where the plot is covered by grapes and surrounded by a bund of 0.3 m high. The initial condition was the measured water content profile in May, when the soil profile was already wet from the first rainy season. The amount of evaporation from the soil profile appears to be lower than it should be for grapes during this period of the year, but it was later discovered that this was due to the presence of leaking pipe near the access tube. The true evapotranspiration rates were between 3.3 and 4 mm/d as calculated later. The leaks from pipe was stopped on 6 July by building a barrier to divert this water from the site of measurements. Consequently the depletion of soil profile water by evapotranspiration increased to 3.3 mm/d in the period between 6 July and 18 July.

The field was irrigated twice, with applications of 140 mm on 17 June and 80 mm on 23 July, and collected 60 mm of rain in August. The actual measured rain at Sana'a airport station was 37 mm, however due to the structure of the cultivated plots (plate 4.2), which allows these plots to collect rain water from larger area (rainfall harvesting scheme, chapter 1) the plot received about 64 mm of rain. Since the start of measurements, soil water was flowing downward through the lower boundary. In July, the flux at lower boundary reversed and 2 mm entered the column. Over the entire period of measurements of 92 days, 52 mm of water passed out at the lower boundary of the modelled profile, derived mostly from irrigation (73%), largely as a result of the over-irrigation on 18 June, but with contributions from first rainy season. A summary of fluxes are given in Table 4.7 and illustrated in Figure 4.7.

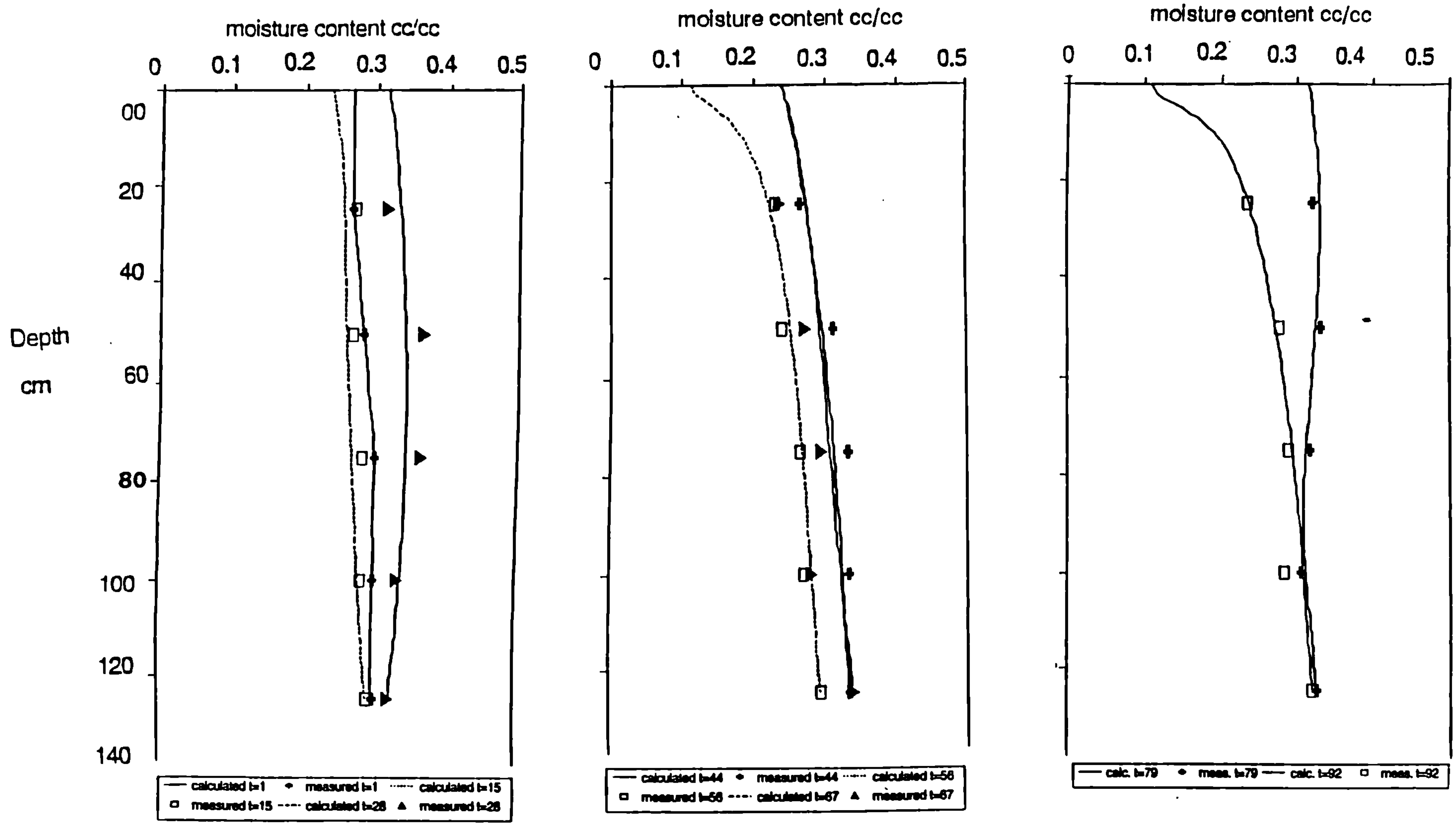
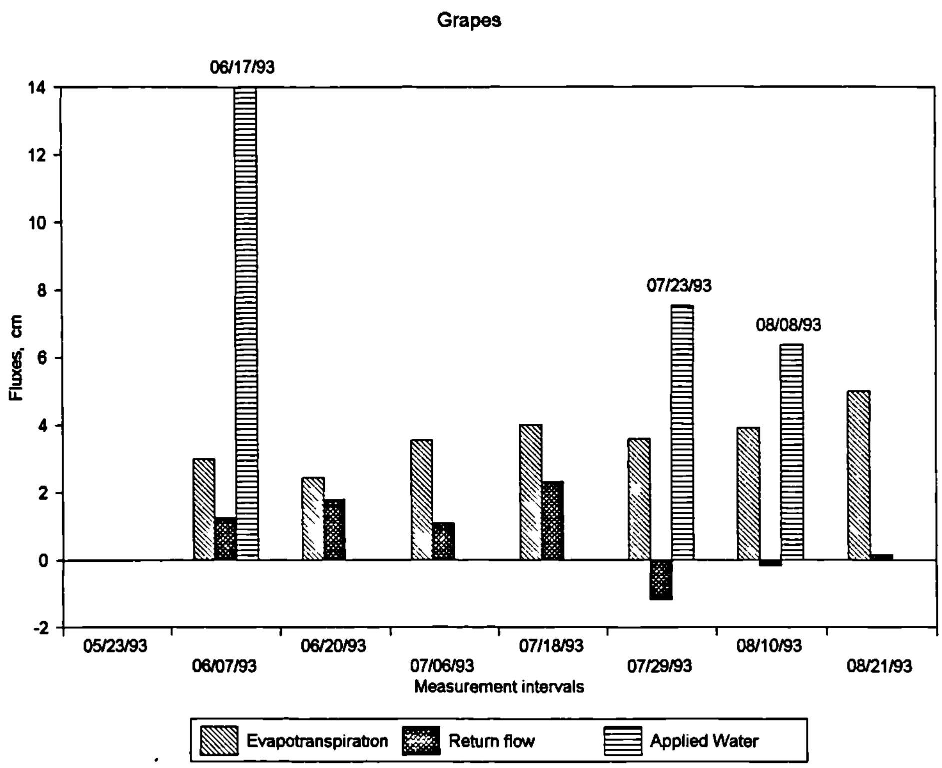


Figure 4.6 Measured and predict water content profile, under irrigated grapes

(a)



(b)

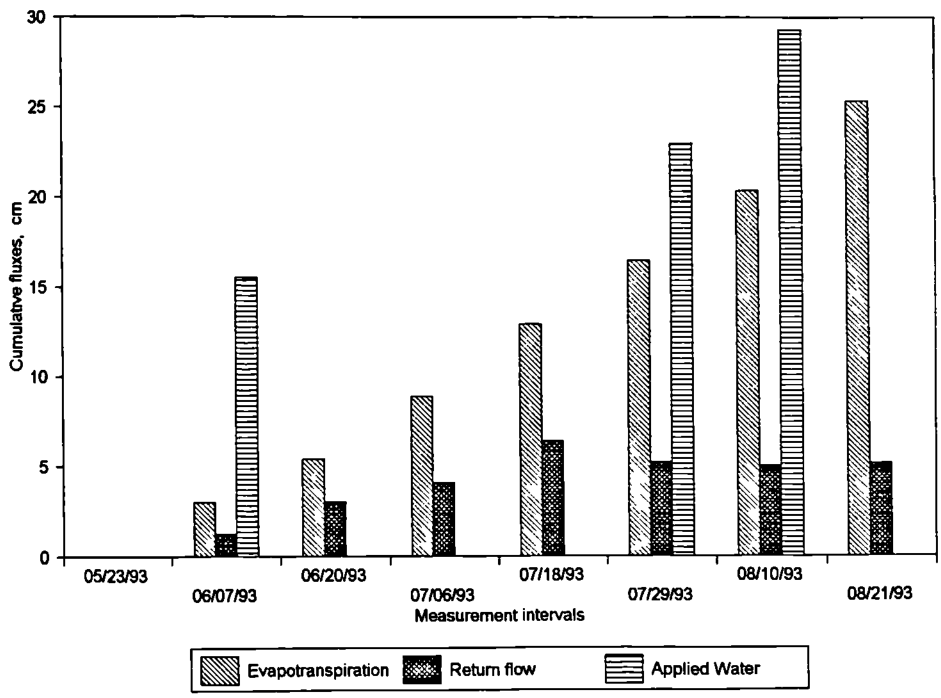


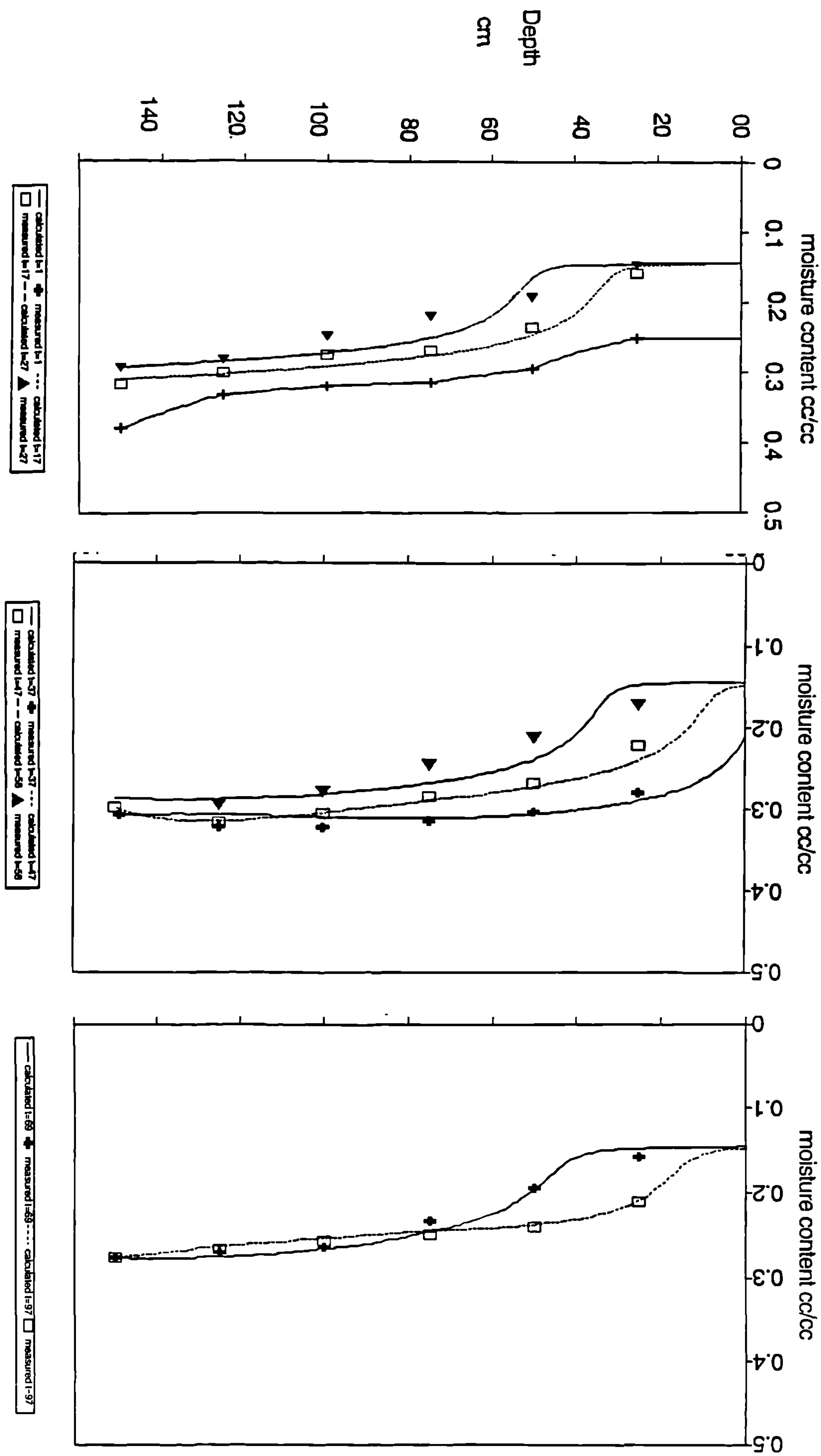
Figure 4.7 Graphical presentation of; (a) Fluxes at upper and lower boundaries of soil 5ir column (b) Cumulative fluxes.

Table 4.7 Summary of CHEMFLO Results at Sawan

Date	Days of time interval	Soil water flux across upper boundary cm	Soil water flux across lower boundary cm
23.5.93			
07.6.93	15	2.9988	1.2513
20.6.93	13	2.4191	1.7852
06.7.93	16	3.5250	1.0761
18.7.93	12	3.9950	2.3007
29.7.93	11	3.5690	-1.1668
10.8.93	12	3.8940	-0.1931
21.8.93	11	5.0000	0.1480
Total	90	25.4009	5.2014

4.4.3 Return flow under irrigated qat

Measurements at AlOzari were made over a period of 97 days, when the site received a total of 77 mm of rainfall and 144 mm of irrigation water. Measured and predicted soil moisture contents are shown in Figure 4.8. The rains of 8 and 9 August 1993, created ponding of water over the site so measurements on 9 August could not be carried out. The model results (Table 4.8) showed that 42 mm, 20% of the total application, infiltrated below the root zone. A total 24.2 mm (57%) of this water was derived from early rainfall in May, which ensured that the soil was wet at the start of the growing season.


Depth
cm
moisture content cc/cc
calculated t=1 measured t=1 calculated t=17
measured t=17 calculated t=27 measured t=27
calculated t=37 measured t=37 calculated t=47
measured t=47 calculated t=56 measured t=56
calculated t=69 measured t=69 calculated t=97 measured t=97

The changes in the flux rate are illustrated in Figure 4.9 which shows the progressive drying out of the soil after rainfall and the repetition of this cycle after the first irrigation on 18 June. Figure 4.10 shows a comparison of the measured and modelled profiles of total head during the second period. This indicates that as the soil dries out, there is a downward shift in the zero flux plane, which divides the upper section with an upward hydraulic gradient from the lower section where water moves downwards. The evapotranspiration rate averaged 3.5 mm/d, but dropped to 2.1 mm/d as the availability of water reduced, reflecting the drought tolerant qualities of qat (Al-Eryani et al, 1992). This site is therefore characterised by relatively low irrigation rates, due to the crop type and to slow infiltration in the silty soil. The slowness is also shown in the flux at the lower boundary, the downward flux decreased from 4.78 cm just before the rain of 8 August to 4.21 cm on the last measurement on 24/8/93, which indicates the delay time for the infiltrated rainwater to reach the lower boundary, as indicated from the upward flux of soil water during the period between 28/7/93 and 25/8/93. (negative flux, see Table 4.8).

Table 4.8 Summary of CHEMFLO Results at AlOzari

Date	Days of time interval	Soil water flux across upper boundary cm	soil water flux across lower boundary cm
20.5.93			
06.6.93	17	6.1200	2.0294
16.6.93	10	3.1680	0.6443
26.6.93	10	4.8000	-0.2522
06.7.93	10	3.1200	0.5500
17.7.93	11	3.8800	1.3199
28.7.93	11	2.2493	0.3856
25.8.93	28	7.4323	-0.4633
Total	97	30.7696	4.2137

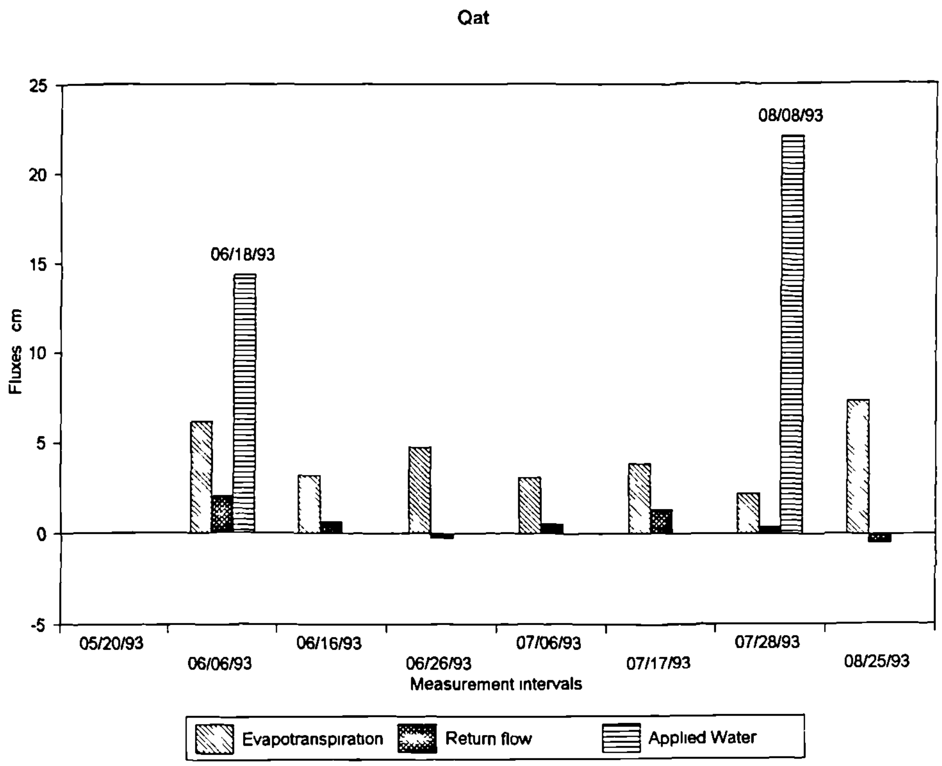


Figure 4.9 Graphical presentation of Fluxes at upper and lower boundaries of soil 6ir column.

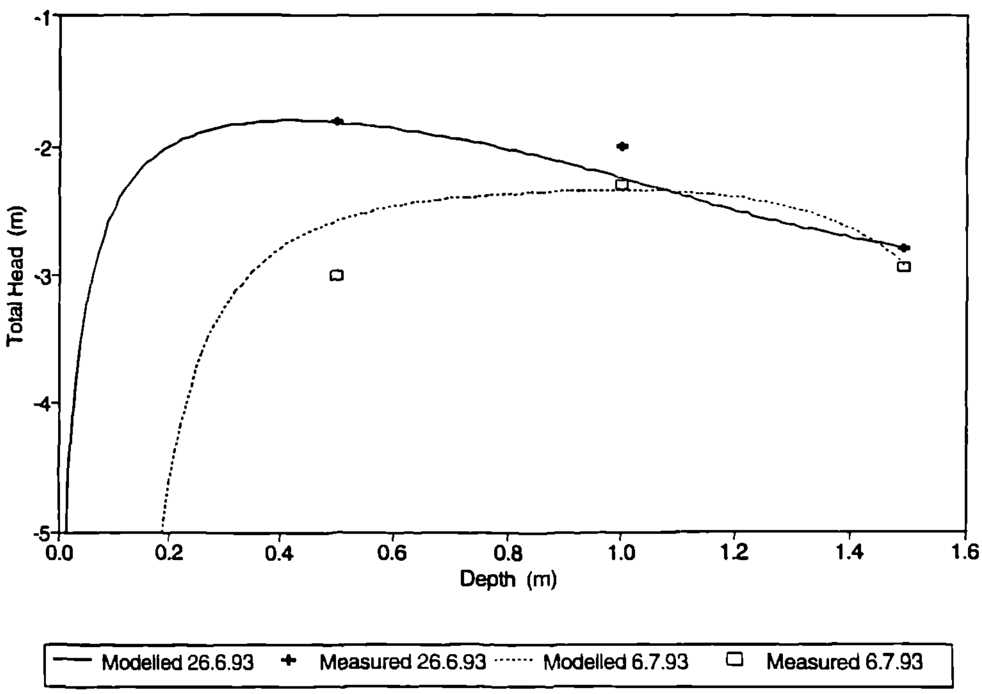


Figure 4.10 Measured and modelled profile of total head (AlOzari site).

Summary of the all results from the three sites, AlRawdha, Sawan and Al Ozari are given in Table 4.9.

Table 4.9 Summary of the irrigation return results for three crops at three different sites.

Site	Soil	Crop	% return from irrig+rain	% return from irrigation
AlRawdha	4ir	Apples	42	51
Sawan	5ir	Grape	18	23
AlOzari	6ir	Qat	19	30

4.5 Regionalization

To regionalize the point value estimates, data on irrigated area, crop pattern, and irrigation water use are required. A review and evaluation of all previous estimates and the data on which the parameters were based was carried out first, in an attempt to clarify the confusion and uncertainty over these parameters. Since the 1970s various groups, such as Italconsult (1973), Howard Humphreys (1983), Charalambous (1982), Dubay et al (1984), Laredo et al (1986), Mosgiprovodkhoz (1986), Chaudary and Turkawi (1990) and Al-Eryani et al (1992), have attempted to estimate the amount of water being pumped for irrigation. Although there appears to be little or no agreement among the study groups on the level of groundwater used for irrigation, there was general agreement that irrigation use was growing at the highest rate of all the groundwater uses in the Sana'a basin. Mosgiprovodkhoz (1986), however, reported that there was no change in groundwater abstraction for irrigation during the period between 1978-1985 in the wellfield area. The reasons for uncertainty are related to the poor estimation of irrigated areas, cropping pattern and irrigation water requirements. These are described below.

4.5.1 Irrigated area & Cropping Patterns

There is uncertainty in the estimates of the area irrigated by groundwater in the Sana'a basin. This is caused by the Russian team (Mosgiprovodkhoz, 1986) who reported two different figures for irrigated area in the Basin. The more clear one is 3000 ha, and most of the other studies criticized this value, which is clearly too low. The second figure is 7500 ha, mentioned in the Soil final report, (volume 3) as irrigated soil, which has not been mentioned by any of the subsequent investigators. However, they have attempted different methods to estimate slightly higher values for the irrigated area and a review of these estimates are given below;

Laredo et al (1986) used an irrigated area of 13000 ha (of which 5592 ha are qat plantations in Hamdan District) to estimate crop water requirements in the Sana'a basin. They assumed that Hamdan District falls entirely in the Sana'a basin, However, only 70% of the District falls in the Sana'a basin. They mentioned the qat irrigated area only. However, irrigated grapes and irrigated sorghum are also found in Hamdan area. From data for Sana'a province (Chaudry and Turkawi, 1990) irrigated grapes and sorghum occupied 677 ha and 624 ha, respectively during 1984/85. This means the actual irrigated area in Sana'a basin, as estimated by Laredo et al, would be 8157 ha. The slight difference can explained by other irrigated crops (e.g. barley, vegetables etc).

Nash (1991) attempted to estimate the crop water use for the Sana'a basin in 1984, using a cropped area of 10229 ha based on Chaudry and Turkawi (1990). However as Nash reported, Chaudry considers the census figures are less reliable at the district level. Al-Eryani et al (1992) used the number of the existing wells as reported by Grover (1986), (3725: 1768 boreholes and 1957 wells) and the average seasonal command area per well, as estimated by Hossain and Nouman (1991),i.e 3.23 ha for boreholes and 2.89 ha for open wells, to give an estimate of total irrigated area in 1984 of 11366 ha. This is an overestimation of the irrigated area, probably because they assumed all boreholes and wells are operating.

From the above, it can be concluded that 7500 ha as understood from final report volume 4 "land reclamation assessment" and also on the enclosed map (Mosgiprovodkhoz, 1986), is the correct figure for the irrigated area in 1984, whereas the 3000 ha applied to "stable farm", i.e farms with an irrigated area of more than 50 % of its total area. These farms exist all over the basin and not only over the plain. The 4500 ha represent farms with irrigated area of less than 50%, scattered all over the basin, and the areal extent can be read from the soil types with subscript ir (Table 4.1).

Mosgiprovodkhoz (1986) failed to present data on the change in land use with time. Al-Eryani et al (1992) manipulated raw data of a sample of 2557 farm holdings (45.38 sq.km) in 10 Districts within Sana'a Governorate for 1990, in order to show the change in farmland pattern during the past few years (i.e. 1984-1990). It was found that inactive cropland covers about one fifth, while irrigated areas occupied one third of the total sampled farmland. Assuming the sample was representative for the whole basin the irrigated area would be 35000 ha in 1990 (or 39000 ha in 1993). The large difference between farmland pattern in 1984 and 1993 (Table 4.10a) suggest an overestimation of the irrigated area, even with an irrigated area of 7500 ha in 1984.

Table 4.10a Farmland categories, in 1984 and 1993 (compiled from Mosgiprovodkhoz, 1986 and using similar percentages reported in Al-Eryani et al, 1992)

Category	1984 (Mos.) Area ha	Percent	1993 (Al-Eryani et al) Area ha	percent
Active cropland	99050	93	93934	80.6
Rainfed	91550		(54425)	(46.7)
Irrigated	7500		(39509)	(33.9)
of which G.W			[38925]	[33.4]
Inactive cropland	7510	7	22609	19.4
Total	106560	100	116543*	100

* Assuming growth rate of 1% since 1984.

It should be mentioned that abnormal growth in the agricultural production, and consequently in the irrigated area, would be expected from 1986/1987 when the government abandoned the import of vegetables and fruit; however, it is believed that the above percentage is too high, at least for the irrigated area. It is not known why Al-Eryani et al did not make use of the result of the agronomy study carried out by Italconsult in 1972 to show the change in the farmland with time for longer period. Although Italconsult's definition of Sana'a basin was smaller than defined later, their data can be assumed as a representative sample of the Sana'a basin, especially as the area covered by the agronomy study was larger than the area sampled reported in the Agricultural Statistics Project.

An attempt to extrapolate the farmland changes between 1972 and 1993 was carried out using all available data, i.e Italconsult (1973), Mosgiprovodkhoz (1986) and Al-Eryani el al (1992), as described below. By assuming 1% annual growth rate of the cultivable land from 1972 to 1993, the farmland category in 1972 over the all Sana'a basin (3209 km^2) was estimated by multiplying the percent of each category as reported by Italconsult (1973). The results of the agronomy study in 1972 are given in Table 4.10b, together with the extrapolated areas for 1972 applied over the whole basin. Then the farmland patterns over Sana'a basin between 1972 and 1984 were linearly interpolated from this estimate and Russian farmland pattern (Table 4.10a). The detailed annual results are given in Appendix B

Table 4.10b Farmland categories in 1972 (compiled and modified from Italconsult (1973).

Category	Reported Area, 1972 ha	Percent	Extrapolate area, 1972 ha
Active cropland	23050	95.6	90215
Rainfed	22000	91.3	86145
Irrigated	1050	4.4	4111
of which G.W	750	3.1	2937
Inactive cropland	1050	4.4	4111
Total	24100	100	94368

The farmland pattern for 1990 has been based on an indicative cropping pattern and intensity (by source of water) in Sana'a basin's active cropland compiled and modified by Al-Eryani et al (1992). Using new data from the Agricultural Statistics Project during the growing season of 1990, the results are that 80.6% of the basin is active cropland, of which 67% is rainfed, 23% is irrigated by groundwater and 1% irrigated by surface water. Using these results, the farmland pattern of 1993 was estimated by assuming 1% increase of the cultivated area since 1990. The distribution of the farmland in 1993 is given in Table 4.10c, and the farmland pattern between 1984 and 1990 were interpolated linearly. The detailed annual results are given in Appendix B.

Table 4.10c The Corrected Farmland categories in 1993, (compiled and modified from Al-Eryani et al. 1992)

Category		Area ha	Percent
Active cropland		93934	80.6
Rainfed	71390		(61.3)
irrigated	22544		(19.3)
of which G.W	(21605)		(18.5)
Inactive cropland		21945	19.4
Total		116543*	100

*Assuming growth rate of 1% for the overall farmland since 1984

The cropping pattern over the irrigated area in the Sana'a basin for 1972 (Italconsult, 1973), 1984 (Mosgiprovodkhoz, 1986) and 1993 is given in Table 4.11 after corrected for irrigated area. The cropping pattern for 1991-1993 was estimated from the cropping pattern of

1990 (Al-Eryani et al (1992), using annual growth rate suggested for different crop growing in the Sana'a basin by TSHWC (1992).

Table 4.11 Cropping pattern for different crop growing in Sana'a basin (Compiled and modified from Mosgiprovodkhoz, 1986 and Al-Eryani et al, 1992).

Crop Pattern	Area 1972 (ha)	Area 1984 (ha)	Area 1993 (ha)
Sorghum	793	372	1728
Wheat	294	761	432
Barely	822	1227	432
Maize	294	548	216
Tomatoes*	294	1250	1945
Potatoes*	59	801	1945
Alfalfa	176	549	1512
Grapes	59	697	4753
Qat	147	1195	7993
Other trees	0	100	649
Total	2937	7500	21605

* or other vegetables

As can be seen from Table 4.11, the cropping pattern is mainly dominated by cash crops, such as qat, grapes and vegetables. The change in the cropping pattern between 1984 and 1993 was linearly interpolated, and in fact, the shift in the cropping pattern reflects farmers' response to relative profitability of various crops. There is a decline in cereals and an increase in cash crops.

4.5.2 Crop water use and requirements

Italconsult (1973) estimated water use by crops over a limited area based on their agronomic study. The result was close to that of the well inventory for the same area, so the irrigation water consumption for the basin 'study area' was estimated as 6.6 MCM/year. The Russian team, Mosgiprovodkhoz (1986) estimated irrigated crop water consumption, mistakenly reported as requirement, as 33.5 MCM/yr during 1984. Nash (1991) used a cropped area of (10229 ha) and water requirement coefficients based on Chaudary and Turkawi (1990), to arrive at a value of 124 MCM/yr for crop water requirements. With the same cropped area, using water use coefficients from Italconsult, Nash estimated 43 MCM/yr for crop water consumption in 1984/85.

The irrigation applications from groundwater observed during the present study for certain crops (qat, grape, vegetables and fruits) are given in Table 4.12, together with previous studies' estimates for water consumption and requirements per hectare. Figures for crops not observed in the present study were estimated using information from farmers, with irrigation water consumption as suggested by Italconsult, as their estimate was based on field observation.

Table 4.12 Irrigation water requirement(IWR) and consumption(IWC) per hectare for different crops grown in the Sana'a basin

Crops	IWC/ha (Ital, 1973)	IWC/ha[1] (Mos, 1986)	IWR/ha[2] (TSHWC, 1992)	Applied[3] ground water/ha	IWC/ha[4] e.g 1993
Grapes	5200	4400	14000	8000	10700
Qat	3900	4400	12050	7000	9700
Sorghum	3200	5300	7410	3200	5900
Barley	3900	4400	6220	3900	6590
vegetables	4320	6400	9420	4500	7200
Fruits	-	-	7410	8000	10700
Wheat	4550	5200	6220	4550	7250
Maize	4550	5500	7530	4550	7250
Alfalfa	22750	14200	16780	14500	17200

Notes:

1 Russians estimation based on equation (ETc - effective Rain - change in soil moisture - water from groundwater), the irrigation efficiency was not included. They called it water requirement but it rather water consumption.

2 IWR estimated from (ETc-Effective Rain/irrigation efficiency) and for non-cash crops 30% has been deducted.

3 The actual applied irrigation groundwater observed during the study.

4 Total applied water, after considering effective rainfall, (effective rainfall for 1993 was 269.2 mm)

It is clear from Table 4.12 that the cash crops are grown under conditions of little or no stress (i.e irrigation meets full consumptive needs). The cereals and non-cash crops received up to 50% less water than their theoretical water requirements.

4.5.3 Sana'a Basin Irrigation Return

Using data on the irrigated area, crop pattern and water use for each crop, the applied groundwater for irrigation over the basin between 1972 and 1993 has been computed. The percentage of irrigation return to the shallow aquifer for qat, grapes and fruit during 1993 was estimated digitally as 29%, 23% and 51%, respectively (section 4.4). Similar proportions have been used to compute the irrigation return from the three crops between 1972 and 1993. An average percentage of 34 % has been used to compute the irrigation return for other crops for the period between 1972 and 1993. The results are given in Table 4.13. and illustrated in Figure 4.11, with the detailed calculation for each crop are given in Appendix B.

Table 4.13 Irrigation Return over Sana'a Basin (1972-1993)using groundwater abstraction and irrigated area

year	Irrigated area, ha	Total abstraction MCM	Total Return MCM
1972	2937	14.1	4.7
1973	3317	16.5	5.5
1974	3698	19.0	6.0
1975	4078	21.5	7.0
1976	4458	24.0	7.8
1977	4838	26.5	8.6
1978	5219	29.0	9.3
1979	5599	31.4	10.1
1980	5979	34.0	10.9
1981	6359	36.4	11.7
1982	6740	38.9	12.5
1983	7120	41.4	13.2
1984	7500	43.9	14.0
1985	9104	55.7	17.5
1986	10708	67.6	20.9
1987	12312	79.5	24.4
1988	13916	91.3	27.8
1989	15519	103.0	31.3
1990	17123	115.0	34.8
1991	18617	126.0	38.0
1992	20111	138.0	41.2
1993	21605	149.0	44.5

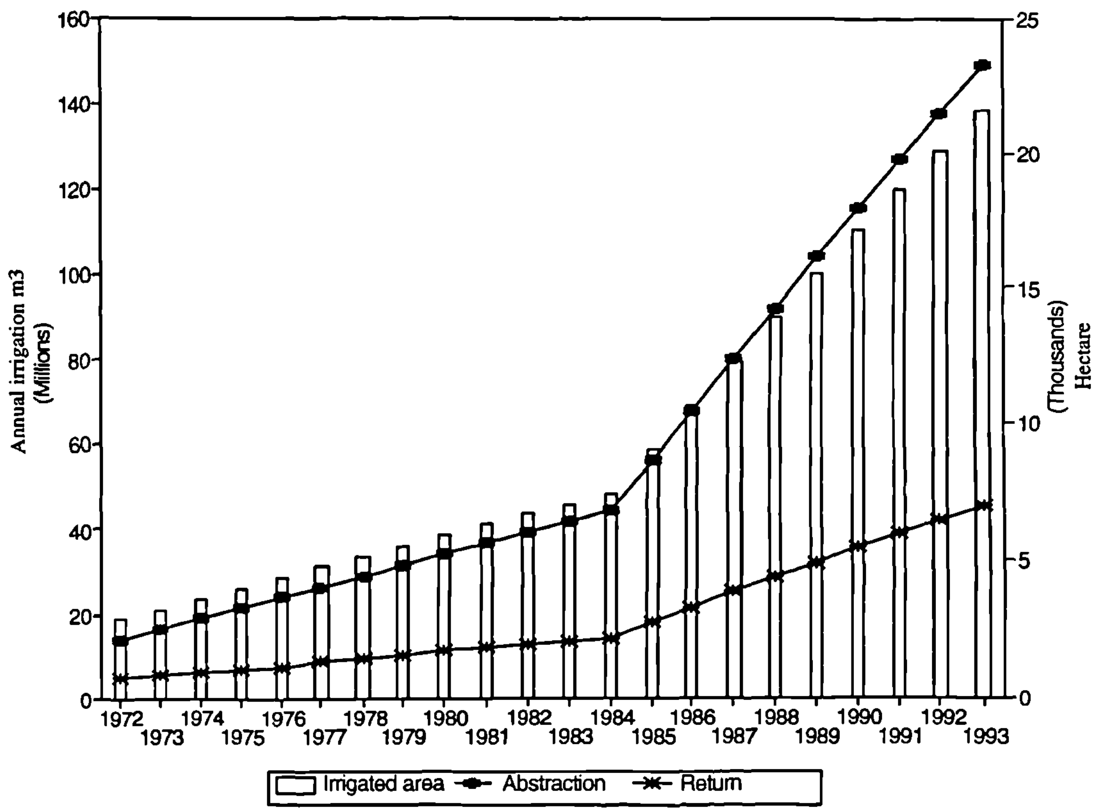


Figure 4.11 Irrigated area, irrigation abstraction and irrigation return over the basin (1972-1993)

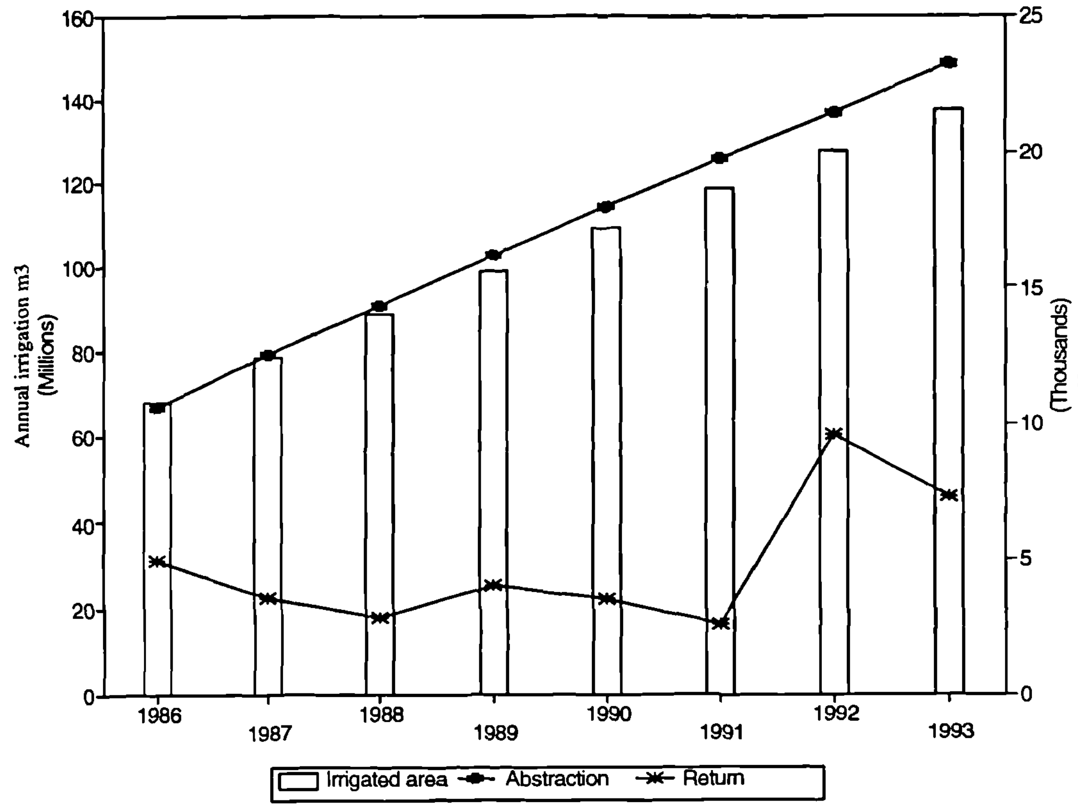


Figure 4.12 Irrigated area, applied water and irrigation return (1986-1993).

The linear increase of the irrigated area is reflected in the linear increase of the irrigation return between 1972 and 1993. The slight increase in the abstraction however, may attributed to the change in the crop pattern.

However, it has been observed during the present study that the proportion of irrigation return is also influenced by rainfall events, rather than the applied groundwater alone. To show this effect, another procedure was used to extend the irrigation return of 1993 over previous years, however, the availability of daily meteorological data made this possible only for the period between 1986 and 1993. The procedure uses a water balance approach and is described below;

The total applied water for various crops during 1986-1993 was computed as the sum of the applied irrigation water (column 6 in Table 4.12) and the effective rainfall for each year. The annual effective rainfall was estimated from the rainfall-runoff model (chapter 5) which is capable of computing the losses and the runoff amount from rainstorms over each runoff characteristic zone. Due to the limitations of the data, this has been done for two wadis, namely, AlSir in the eastern part and Dhar in the western part of the basin. Then the average of rain losses over the cultivated area from these two wadis was assumed to equal the effective rainfall over the whole basin. The losses over each wadi, and the average are given in Table 4.14

The components of the annual water balance equation are;

Irrigation Return = Applied water - Actual evapotranspiration

where

applied water= Applied ground water + Effective rainfall

Effective rainfall = Rain ± Runoff

Table 4.14 Effective rainfall as estimated from Rainfall-Runoff model

Year	Effective rain, Wadi Dhar mm	Effective rain, Wadi AlSir mm	Average Effective rain mm
1986	344.5	352.1	348.3
1987	219.1	239.9	229.5
1988	190.4	248.0	219.2
1989	216.6	197.7	207.2
1990	261.3	189.9	225.6
1991	205.3	105.5	155.4
1992	346.6	323.0	334.8
1993	292.0	246.4	269.2
average			248.6

The actual evapotranspiration has been computed using the Penman-Monteith equation for the period between 1986-1993 for which daily meteorological data records for Sana'a airport are available. As discussed in chapter 2, canopy resistance 'rc' has been evaluated for each crop from the results of the numerical simulation for the three crops; qat, grape and apple. The estimated rc was used to calculate the actual evapotranspiration for these crops over the period between 1986 and 1993 (chapter 2).

The amounts of applied water during the same period were computed from the estimated irrigation water, and the effective rainfall from rainfall-runoff model. Then by applying the above equation, the irrigation return was computed for qat, grape and apple and over the period 1986-1993. The results are given in Table 4.15.

Table 4.15 The actual applied water for three main crops, and the percentage return to the shallow aquifer, calculated by water balance method.

year	Water applied for Qat (mm)	% ret-urn	Water applied for Grape (mm)	% ret-urn	Water applied for Apple (mm)	% ret-urn	% Aver-age ret-urn
1986	1048	26.7	1148	23.5	1148	46.3	32.2
1987	929	18.0	1029	14.7	1029	39.3	24.0
1988	919	11.0	1019	8.6	1019	34.6	18.0
1989	907	15.9	1007	13.4	1007	37.9	22.4
1990	925	11.3	1026	8.6	1026	37.1	19.0
1991	855	5.7	955	7.8	955	31.4	15.0
1992	1035	28.6	1134	25.1	1134	46.1	33.3
1993	969	20.4	1069	17.8	1069	41.2	26.5
	948	17.2	1048	14.9	1048	39.2	23.8

The average irrigation return for these crops over the period 1986-1993, 23.8% was assumed to equal the percentage of the irrigation return for the other crops. The only justification for this assumption is the lack of information which delineates the crops and the soil type together. However, the observations were carried out for the two leading crops in the basin, qat and grape which cover about 60% of the irrigated area.

The annual results for the whole basin between (1986-1993) are given in Table 4.16 and illustrated in Figure 4.12. The detailed information about interpolation of the irrigated area, applied irrigation ground water and total water consumption for each crop are given in Appendix B.

Table 4.16 Annual irrigated area, water consumption and irrigation return over Sana'a Basin, (1986-1993).

Year	Irrigated area, ha	Irrigation water, MCM	Total consumption MCM	Return MCM
1986	10708	67.6	105	31.0
1987	12312	79.5	108	22.5
1988	13916	91.3	122	17.4
1989	15519	103.0	135	25.3
1990	17123	115.0	154	22.3
1991	18617	126.0	155	16.3
1992	20111	138.0	205	61.5
1993	21605	149.0	207	46.7
Average				30.4

The annual average irrigation return for all irrigated crops in the basin over the period (1986-1993) was 30.4 MCM. Using the same period, the annual average irrigation return as estimated using groundwater abstraction (i.e first estimate) was 32.6 MCM. This further supports the accuracy of this man-induced component of recharge and represents a considerable amount of groundwater recharge in an arid area with limited water resources.

5 WADI FLOW

5.1 Introduction

Although annual precipitation over the Sana'a basin is low to moderate, rainfall occurs sometimes as a high intensity events, which often lead to wadi floods, particularly as large parts of the area surrounding the wadis are mountains with steep slopes and impervious rocks. Logistic and material problems peculiar to arid zones impose special problems in gathering sufficient data to study runoff in such conditions. The scarcity of runoff data has led hydrologists, to try to locate traces of the latest floods or the most violent flows and subsequently to make use of these data for the calculation of discharge. The situation in Sana'a basin is not much better from that situation. However runoff data of a qualitative nature has been reported by the Russians in 1986 (Mosgiprovodkhoz, 1986), as a result of their extensive studies of the terrain, rainfall and flow (including enquiries about recent and previous floods) over a period of up to 15 years. However, they obtained few direct measurements of wadi flow because their gauging stations were vandalized.

Extensive field work was carried out during January to September 1993 to collect the parameters that are required for recharge calculation. These include; wadi flow observations at three selected wadis, wadi channel sedimentation, visits to all wadis within the basin, questioning of the locals, and checking the relief and geomorphological characteristics of wadis with the available maps. A description of the sites selected for measurement and the field procedure used to measure and estimate the wadi flow is given in section 5.2. Processing of the data collected is described in section

5.3, followed by description of the wadi flow characteristics.

Collection of complete and reliable data sets concerning flood hydrograph characteristics in Yemen, as in most arid zones, is a difficult and expensive task. The measurements during the present study cover only three wadis and a short period of time. However, these data were used as the seed to establish a rainfall-runoff model capable not only of extending the duration of wadi flow estimates over the three wadis, but also of application to ungauged wadis to estimate wadi flow over the last two decades, with a minimal requirement for input data. Section 5.5 describes the approach, calibration, and results of the rainfall-runoff model.

5.2 Measuring techniques

This section describes briefly the wadis and the procedure followed in the field, from choice of the reach to measurements.

5.2.1 Site description

Three main wadis have been selected for wadi flow measurements. These are wadi alSyla, alRawna and Dhar and their locations are shown in Figure 5.1.

Wadi alSyla is located in the central part of the Sana'a plain and drains an area of 690.5 km^2(Region C), Figure 2.1, with a channel length of 46 km. It runs from the south where the Quaternary deposits are underlain by Tertiary basalts (90.5 km^2), through Sana'a city to the north, where the Quaternary deposits are underlain by Cretaceous sandstone (175.4 km^2), and further north by the Amran Group (65.2 km^2). The rest of the catchment area consists of Tertiary volcanics. If all the primary wadis discharged into Wadi alSyla, the main channel of Sana'a basin, the catchment area would be larger, but because the flows from these wadis usually disappear before reaching the Plain, region C has been treated separately in the calculations. The observation station is located within the city 11 km from the upstream end, at a straight and uniform reach covered with sand. Several minor channels (Canals) from either side and along the channel drain into the main channel. The reach selected for observation has a catchment area of 113 km^2 (plate 5.1a).

Wadi alRawna lies in the eastern part of the basin, with a catchment area of 76.6 km^2. The wadi, which is developed along a major fault zone, has a well defined channel 25 km long. The valley varies in width from several hundred metres to several thousand metres, widening in the downstream direction. In the higher order tributaries and the upstream reach, the valleys are canyon shaped or V-shaped in cross section, and their bottoms are covered with lumpy boulders of basalt and are inaccessible with a high slope. Volcanic rocks of Tertiary age, in which basalts are predominant, cover 73 km^2 of the catchment. Quaternary loose deposits are mainly found on the wadi bottom at downstream reaches, where the area is usually terraced beside the gentle slopes. Cretaceous Sandstone is found beneath the Tertiary volcanics at varying depths, for example at Alrawna village at 250 m, (verbal information from drillers). The reach selected for observation is located 19 km downstream from the upstream border of the catchment and has catchment area of 48.7 km^2. The reach is straight, with well defined banks and covered mainly with gravel (plate 5.1b).

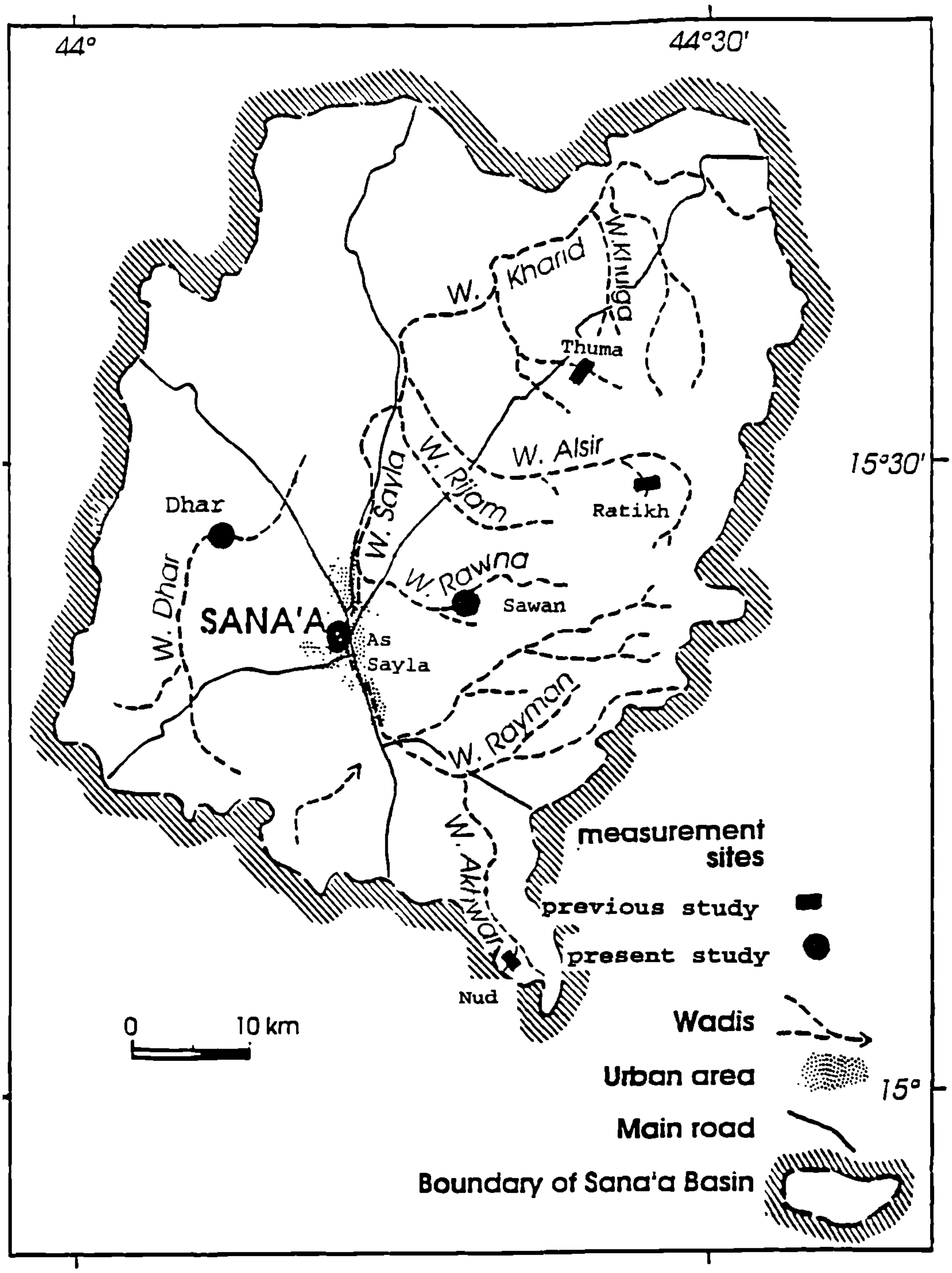


Figure 5.1 Location of Wadi flow observations

The catchment of Wadi Dhar occupies almost all the south western part of the basin, the wettest and most populated part of the basin. This wadi drains an area of 371 km^2 and has a channel length of 35 km, along which the total elevation change is about 600 m. Morphologically, the wadi can be divided into two different characteristic reaches. The upstream reach (orientated north-south) has a trough shaped valley 1 km or more in width, and a gradient of 0.5 -1.5 % along the wadi channel. The second reach runs eastward and has a length of 10 km, starting from bayt Na'am. The slope here are sharply increased and the valley looks like a steep-sloped canyon 200 -350 m wide. At the extreme debouchment, the valley widens as it approaches the Sana'a (piedmont) plain, to more than 8 km. Cretaceous sandstone outcrops over most of the area, forming the plateau, slopes and lying below the Quaternary deposits in the wadi bottom. Intrusive dikes are common in the slopes.

The observation station is located in the lower reach, 2 km from the conjunction (Na'am), above which volcanic boulders almost cover the wadi channel. In the downstream direction however, the sediments become smaller in size, as well as more rounded and sorted. The terraces occupy the whole area of gentle slopes and only in the wadi bottom, a channel, 16 to 20 m wide, is provided for handling the floods. Stone walls of the adjoining terraces vary the channel depth from 3 to 4 m.

Upstream of the lower reach, there was a perennial stream fed by al-Balad spring, a few hundreds metres upstream to the present gauging site. The discharge of Wadi Dhar was measured as 60 l/s, date unknown (Italconsult, 1973). Regular measurements during 1983-1984 were carried out by Russian team (Mosgiprovodkhoz, 1986), with average discharge of 7.5 l/s (350 m^3/d). Five or six years ago, it became an ephemeral wadi, probably due to reduction in rainfall (plate 5.1c).

Plate 5.1a Wadi Al Syla

Plate 5.1b Wadi Al Rawna

Plates 5.1c Wadi Dhar

Plates 5.1c Wadi Dhar

5.2.2 Field procedure

For each of the three wadis, the reach selected for observations and measurements has well defined and permanent banks, free of vegetation. The channels of these reaches are nearly straight and uniform and contracting rather than widening. Except for wadi alSyla which is covered by sand, the two wadis are mainly covered with gravel and boulders. The long-stream bed profile is even with no sharp changes, i.e. the selected reaches meet the assumptions of the slope area method.

Three cross sections were marked out; at the upstream end, downstream end and in the middle of the selected reach. The distances between the sections were measured using a tape measure along the centre of the channel. Each cross section was surveyed using an automatic level and a surveying staff (3 m long), and pairs of distances and elevations were noted. As each survey was carried out for a particular flood which passed one or two days previously, the elevation measurements begin and end at the high water marks on the banks.

Once the surveying was completed, the bed material sizes were measured. A sample of 100 elements were collected from the full width of the channel between the flood-marks. The median axes (Particles have three dimensions, length, width and thickness, and are oriented so that length and width are parallel to the plane of the stream bed, median means width, see Figure 5.2a) were measured in millimetres with a ruler and the value noted on the special data sheet.

For floods occurring after April 1993, elevations were measured by painting graduations on the vertical rock bank of wadi Dhar and on a pipe vertically installed at wadi alRawna. The flood elevation was read by a volunteer observer from the local residents.

Due to difficulty in travelling to the gauging site during floods, the surface velocity of flow was measured only for wadi AlSyla. The velocity was measured using floats because the velocity of the flood can be too great for the use of a current meter, moreover this was not readily available. Measurements of the velocity of flood flow were carried out for 11 floods out of 12 floods, which occurred during the first rainy season, April-May 1993.

The field data comprise flood elevations, surveying data and flood velocities, and are given in appendix C.

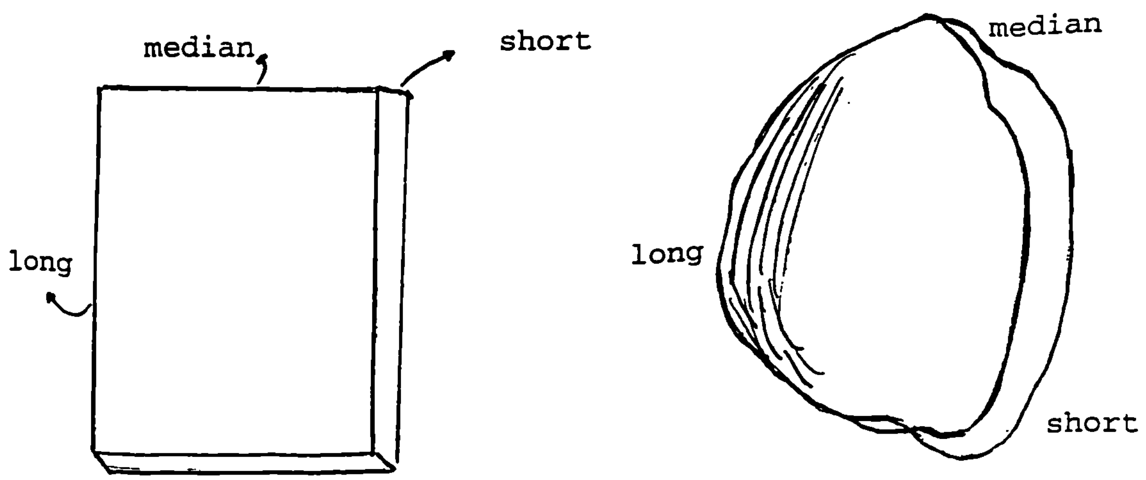


Figure 5.2a Definition diagram for the median axis of bed material element

5.3 Data Processing

5.3.1 Slope-area method

The theory of the slope-area method is not considered here, and a more comprehensive description can be found in Dalrymple and Benson (1967) and Herschy (1985). However, general information on this technique and different opinions are discussed. The method assumes that flow depth and velocity are determined by channel cross-sectional shape, channel slope and bed roughness, and uses theoretical or empirical relationships between these terms to calculate discharge. The simplified, commonly used equation is Manning's equation, which is produced from Chezy's equation of the velocity, V, (V =CRS) for open channel flow by setting the friction factor, C, (C=8g/f) to (C $=R^{1/6}$ /n), (Chow et al. 1988),

$$Q = 1/n\ AR^{2\ 3}\ S^{1/2} = A\ (RS)^{1/2}\ (8g/f)^{1/2} \qquad (5.1)$$

where Q is the discharge (m^3/s), S is the slope of the energy line (in uniform reaches equal to the bed and water surface slopes), g is the gravitational acceleration (m/s^2), R is the hydraulic radius (m), A is cross-sectional area of the flow (m^2) and n is the Manning's roughness coefficient (dimensionless). The friction factor used in Manning's equation is related to the roughness coefficient, n, in terms of the Darcy-Weisbach friction factor f, as follows:

$$n = (f/8g) * R^{1/6} = R^{1/6} /(8g/f) \qquad (5.2)$$

with all values in SI units.

One of the difficulties in applying this method is the accurate estimation of Manning's n. In general, n increases as turbulence and flow retardation effects increase. In a reach where the slope is uniform and the roughness of the bed and banks is similar, Manning's n can usually be assumed constant. However, in natural streams, this may vary. In general, Manning's n can be considered as a calibration factor which integrates the effects of flow resistance caused by bed roughness, the presence (and flexibility) of vegetation, the amount of sediment or debris carried by the flow and other factors (Chow, 1959; Trieste and Jarrett, 1987). Several empirical methods are available to estimate n values, but these are only applicable to areas which are similar to the area for which the equations were derived (Henderson, 1966).

The set of equations used in the present study are those developed by Bathurst in 1983 for the western wadis of Yemen and suit the conditions of the central highland wadis. Although Bathurst (1983) used the common equations of slope area method, neither the source nor the basis for estimation of the resistance coefficient (equation 5.3) for steep wadis with gravel bed were reported. The equations used to estimate the resistance coefficient for sandy bed wadis are those developed by Simons and Senturk (1977).

In order to allow for nonuniform flow effects, caused by variations in cross-sectional shape, measurements of the various quantities were made at three cross sections along the chosen reach.

The friction factor $(8/f)^{1/2}$ was calculated for each section using the equation, (Bathurst, 1983);

$$(8/f)^{1/2} = 5.62 \log (d/D_{84}) + 4 \tag{5.3}$$

for a gravel bed (at alRawna and Dhar) , and

$$(8/f)^{1/2} = 7.4 \log (d/D_{85}) \tag{5.4}$$

for a plane bed, i.e alSyla.

d is the mean depth and can replace the hydraulic radius when the stream width is much greater than depth. It was calculated by dividing the cross section area (A) by the surface width (W), which is the horizontal distance between the high-water marks.

D_{85} is the sand size and may typically be 2 mm for coarse sand (Bathurst, 1983). D_{84} is the size of median axis of the bed material, which is bigger than 84% of the material in a sample. D_{84} for wadi alRawna and wadi Dhar was 0.027 m and 0.063 m respectively. (see Appendix C)

The conveyance factors (K) were calculated for each section using the equation, (Bathurst, 1983);

$$K = A\ (g\ R)^{1\ 2}\ (8/f)^{1/2} \tag{5.5}$$

The peak flood discharge was calculated using equation (Bathurst, 1983);

$$Q = K_3 \sqrt{\frac{\Delta h}{K_3/K_2\ (K_3/K_1 L_{1.2} + L_{2.3})\ +\ K_3^2/2gA_3^2\ [(1-c_{2.3})+(A_3/A_2)^2(c_{2.3}-c_{1.2}) - (1-c_{1.2})(A_3/A_1)^2]}} \tag{5.6}$$

where Δh is the difference in water surface elevation between sections 1 and 3. $L_{1.2}$ is the distance between sections 1 and 2, $L_{2.3}$ is the distance between section 2 and 3 (Figure 5.3). $c_{1.2\ \mathrm{or}\ 2.3}$ is constant assumed equal to .5 when $A_1 < A_2 < A_3$ and equal to zero for $A_2 > A_3 > A_1$, A is cross section flow area, and g is the acceleration due to gravity.

Channel plan view

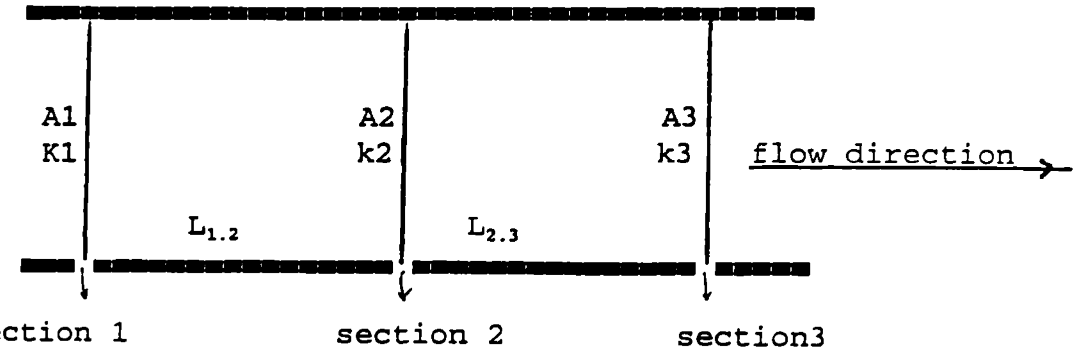


Figure 5.2b Definition diagram for the three sections within the observed reach.

Similar Manning's n values have been obtained by a number of different methods for the wadis under study. A 'calibrated' value, computed by working backwards from the estimated values of discharges and channel dimensions using the formula developed by Bathurst in 1983, produced a value of n equal to that calculated using the equation reported by Limerinos (1970), who included relative roughness in an equation for estimating Manning's n, developed from data on 11 lower gradient channel streams with bed material of small gravel to medium-size boulders. In SI units the equation is given as;

$$n = \frac{0.1129R^{1/6}}{1.16 + 2.0\ \log(R/d_{84})} \qquad (5.7a)$$

where R is hydraulic radius (m) and d_{84} is the diameter (m) for which 84% of the stream bed particles are smaller. Burkham and Dawdyg (1976) showed that the equation applies to the upper regime flow in sand channels, if a measured d_{84} is available or can be estimated.

As Manning's n was estimated for each wadi, it has been used to estimate peak discharge for other floods using the simple form of Manning's equation. As the values of n here included a relative depth parameter, it is believed that they are valid for different water depths. The 'calibrated' n values for wadi alRawna and Dhar are .026 and .031, respectively, and were calculated from the equation;

$$n= (A\ R^{2/3}\ s^{1/2})/Q \qquad (5.7b)$$

Calculations are given in Appendix C.

5.3.2 Velocity-area method

The data required for the Velocity-area method are the area of the stream cross section and the average stream velocity. Area was calculated from cross-section survey data and the velocity measured by observing the rate of travel of a wooden float.

The surface velocity (V_{surf}) was calculated for Al-Syla as

$$V_{surf} = L/t \qquad (5.8)$$

where L is measured reach length (m) and t is travel time (s). Since the surface velocity is higher than the mean velocity, a correction coefficient (k) applied,

$$V = k\ V_{surf} \qquad (5.9)$$

The correction coefficient generally ranges from 0.8 for a rough bed to 0.9 for smooth artificial channels (Herschy, 1978). However in mountain streams, Jarrett (1988) calculated a value as low as 0.67. For wadi alSyla, 0.87 was used as the channel bed here is planar and the bed is levelled artificially (plate,5.1a) by bulldozers (once a year). Then discharge is calculated as;

$$Q = V * A \qquad (5.10)$$

where Q is the discharge (m^3/s), V is the average velocity (m /s) and A is cross-sectional area of the water (m^2). Float measurements can be accurate to within an error margin of 10% under favourable conditions. However in non-uniform sections or where wind is excessive, measurements may be in error by 25% or more (Gordon et al 1992).

By observing the stage and the flow discharge simultaneously, a relationship between the level (stage) and discharge has been developed. Bovee and Mulhous (1978) demonstrated that developing a stage-discharge relationship using only three points produced more reliable results than Manninq's equation, when extrapolated within the range of 40 to 250 % of the calibration flow. They also showed that little improvement was gained by adding more than three points (Gordon et al, 1992). The rating curve can be represented approximately by an equation of the form:

$$Q = a\ (h - z)^b \tag{5.11}$$

where Q is the discharge in m^3 /sec, h is the gauge height of water surface (m) and z is the gauge height of zero flow, a and b are constants (regression coefficients), which were found by a simple linear regression analysis using measured data from wadi Alsyla. Table 5.1 shows the input data used and the values of the regression coefficients. A unique relationship has been obtained, as reflected by the value of correlation coefficient (r), = 0.981. This relationship has been used to estimate the peak discharge where the stage measurements were available. An example for Wadi alSyla is given in Figure 5.3. There is a difference of 9% between values of peak discharge computed by this technique and value estimated by slope-area method for the flood of 6/4/93. (See Appendix C).

Table 5.1 Discharge and Stage measurement used to construct the Rating Curve for Wadi alSyla.

Discharge, Q (m^3/s)	h-z (m)
4.03	0.56
2.26	0.45
1.62	0.40
0.81	0.32

r = 0.981
a = -0.439
b = 0.2767

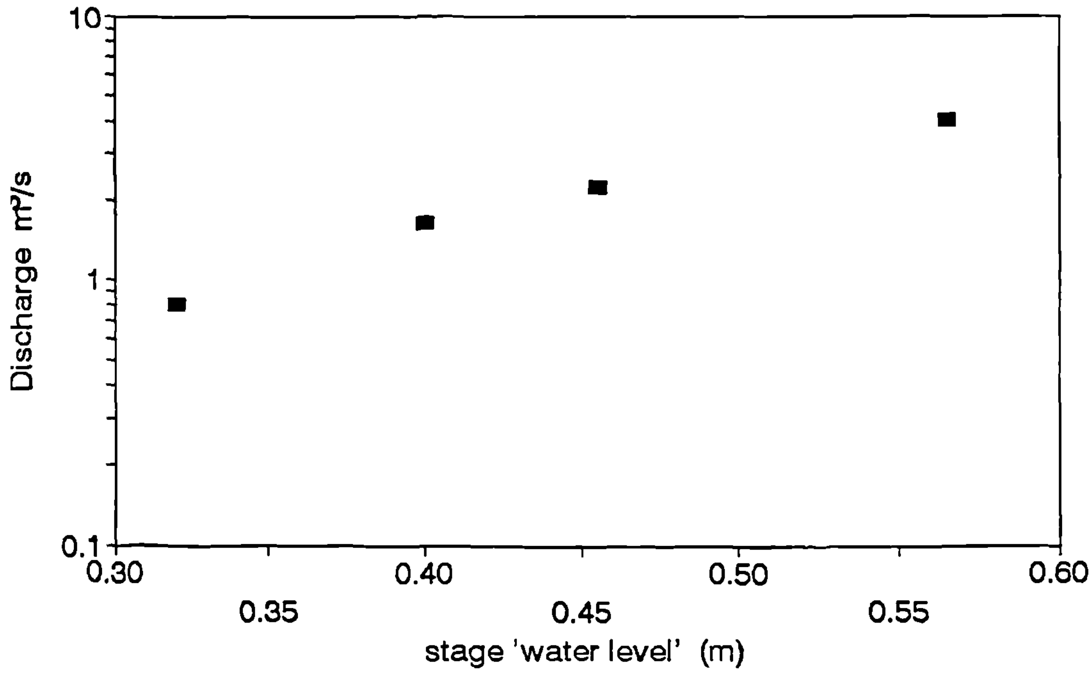


Figure 5.3 Relation between Discharge and Stage developed for Wadi alSyla

5.4 Wadi flow characteristics

A discharge hydrograph shows the flow rate as a function of time at a given location on the stream and is "an integral expression of the physiographic and climatic characteristics that govern the relations between rainfall and runoff of a particular drainage basin" (Chow et al, 1988). The rate at which runoff moves towards the stream (the shape of the hydrograph) is dependent on the drainage efficiency of the hillslopes, the permeability and moisture content of soil, subsurface geology and vegetation cover. The hydrograph shape is affected by these factors, as well as by catchment shape, drainage density, channel characteristics and storm patterns. For example, Wadi Dhar with a steeper longitudinal profile, shows a more rapid response and produces high peak discharge than Wadi alRawna which is less steep.

Although complete and reliable hydrographs have been observed for Wadi alSyla, hydrographs for the other two wadis have been partially estimated using the concept of constant wadi recession (k) and regional relationships between the peak discharge and the duration of flood rise and fall. These relations have been derived by Mosgiprovodkhoz (1986) from measured hydrographs observed in the western wadis of Yemen, as

$$t_r = .039\ Q^{.5} \tag{5.12}$$

$$t_f = 0.728\ Q^{.46} \tag{5.13}$$

where t_r, t_f are time (in hours) of rise and fall respectively and Q is the maximum discharge in m^3/s.

It is noticed from the figures provided by the Russians (Mosgiprovodkhoz, 1986) that the observation line for time of fall fits well with the line drawn using equation 5.13, and agrees with observations made in the present study, but the times of rise show higher scatter between observed and calculated times of rise. Many factors influence the shape of the hydrograph and this scatter implies the presence of other factors which have not been included in the relation. In the present case, it is believed that it is the character of the rainfall event which mainly affects the rate of rise of hydrograph and hence the shape of rising limb. Also the terraces on slopes probably have a major affect.

The hydrograph characteristics of stage height, flood width and duration of flow are the important variables in recharge calculation (e.g Sorman and Abdulrazak, 1993). Since recharge is essentially controlled by infiltration opportunity in space and time, a measure of that opportunity in space is maximum flow width related to maximum stage height through the cross sectional area. The duration of flow represents infiltration opportunity in time.

During the period of the field work between January and September 1993, several floods were observed at three major wadis in the Sana'a basin. The frequency of occurrence of flood in wadi alSyla is greater than for the other two wadis, which is attributed to the effect of urbanization. Floods occurred at the three wadis at the same time as a result of storm rainfall of large extent (>10 mm at Sana'a airport), probably covering all the basin. The spatial variation of the rainfall also has an effect on the occurrence of some floods at one site but not the others. An example is three floods (on 11/4/93, 16/4/93 and 11/5/93) in Wadi alSyla, which resulted from local storm rainfall with limited areal extent, as no rainfall was measured at Sana'a airport during these floods. Moreover the shape of the hydrographs resulting from this rain is different from the other hydrographs which are believed to be generated from the whole basin. In particular for the flood on 11/5/93, the duration of rainfall was about 24 minutes, and resulted in the sharpest hydrograph. The flow in Wadi alSyla was noted to originate mainly from a western channel (small tributary) joining the main channel near the observation point.

Wadi AlSyla shares with the other wadis all the floods, except the first flood on 30.3.93; the reason is unknown, but it is likely to be due to spatial variation of rainfall. The peak discharge observed at wadi Dhar is larger than at the other wadis, probably because of the location of the observation point which is located upstream (7km). The duration of floods generally ranges from 2-3 hours, (confirmed from questioning local residents) with a longer time for the flood of 14/5/93 which has two peaks. However, the recession rate is variable depending upon the peak discharge. The longest recession was observed at wadi alSyla and reflects the shape of the catchment. The observed floods were used to investigate and to verify the results of the wadi flows estimated from the rainfall runoff model.

All hydrographs, field measurements, summary of the floods and their duration are given in appendix C.

5.5 Rainfall-Runoff Analysis

5.5.1 General

If gauged data are not available, then a rainfall-runoff analysis must be performed to determine the flood discharge. In a similar situation of data scarcity, a rainfall-runoff model was successfully applied for Wadi Al-Jawf catchment by Agrar-und Hydrotechnik in 1983. Unfortunately, that model was specific to the Wadi al-Jawf catchment. Similarly TSHWC (1992) developed a Soil Conservation Service (SCS)-model, which was intended for use as a national water planning tool, and hence was of general type that can be transferred from one catchment to another without modification of its structure, because it estimates runoff from each runoff characteristic zone which can then be summed up for any catchment. For application to a new ungauged catchment, catchment physiographic and rainfall data are required, and model parameters require some modification in recognition of the new catchment characteristics. A similar approach was used for the present study to estimate Sana'a basin wadi flow, and the model has been tested against wadi flows measured in the Basin during the present study.

5.5.2 The Approach

In order to take account of spatial variability of daily rainfall and to model the runoff process as realistically as possible, the study area was divided into 3 rainfall zones (section 2.2.4); the south-western, the central and north-eastern and the east-southern part of the basin. Each rainfall zone was further subdivided into 7 runoff characteristic types representing the range of runoff response from the various soils, geology and land uses, which are treated separately within each rainfall zone. The different runoff characteristic zones (ROC) represent different response patterns of the soils in transforming rainfall into direct runoff. A description of the various runoff characteristic zones is summarised in Table 5.2.

This distributed approach is believed to provide the best representation of the wadi's response to rainfall, because of the incorporation of the spatial variability of the rainfall and the differences in land surface throughout the basin, from steep, bare rock to flat alluvial plain and man-made terraces. An example of the areal distribution of these zone over Wadi alSir is shown in Figure 5.4. For the recharge study, these runoff characteristic zones are grouped into two broad classes; "P" runoff-producing zones and "A" runoff-absorbing zones. Although the runoff producing or "P" zones, generate most of the runoff, the "A" zones will generate runoff under the right hydrological conditions of high daily rainfall or a wet catchment.

Table 5.2 Description of different runoff characteristics zones

ROC type*	Description
P1	urban areas
P2	steep slope(>15°) with bare rock
P3	moderate slopes with thin soil
P4	Terraces on slopes
A1	Flat and alluvial areas
A2	Terraces in Wadi beds or on plains
A3	Undeveloped part of wadi bottom

*P are runoff producing zones, A runoff absorbing zones

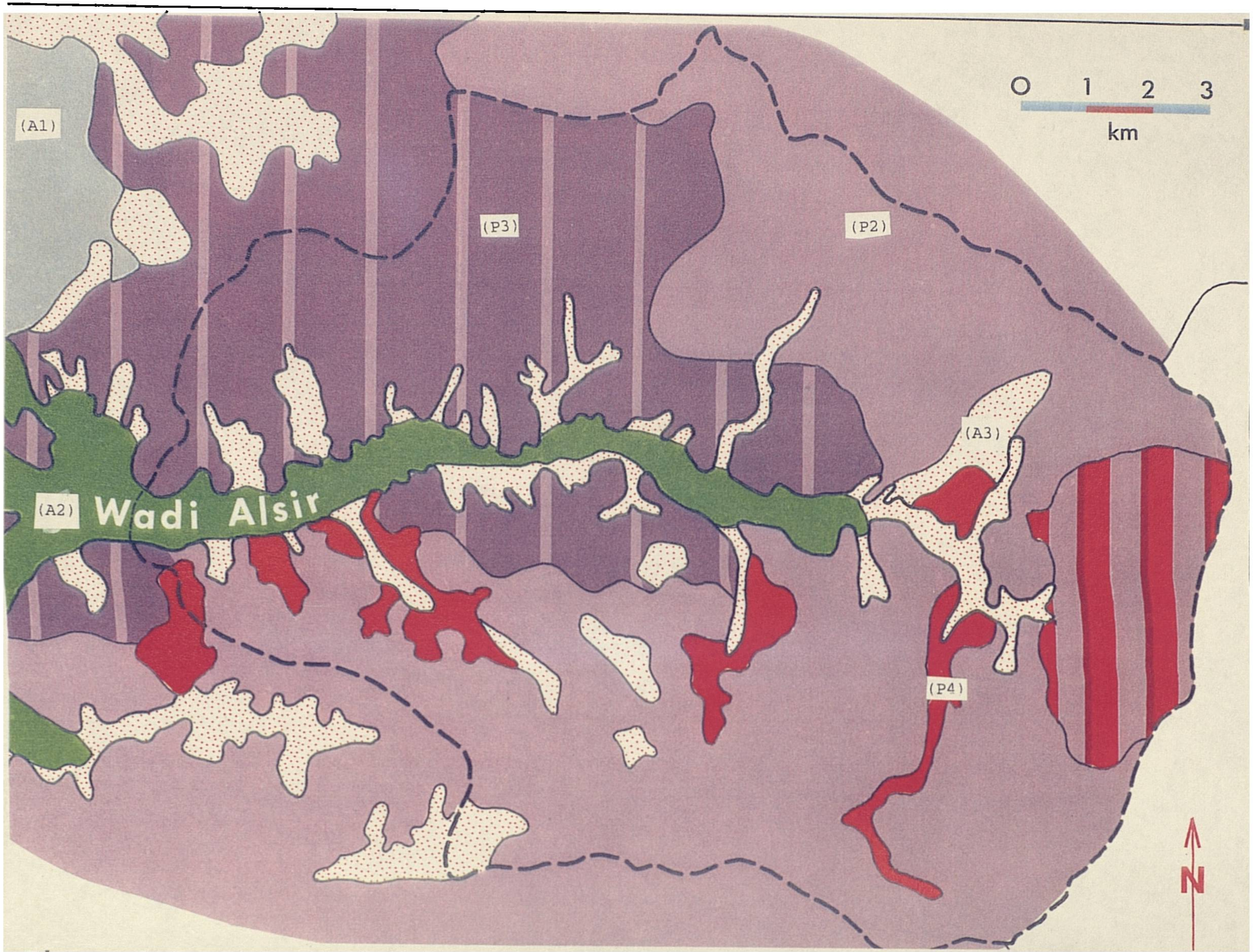


Figure 5.4 Areal subdivision of catchment for modelling (e.g Wadi alSir)

5.5.3 Model description

The method used is that developed by the U.S. Soil Conservation Service (1972) to estimate runoff from storm rainfall for small watersheds. The method assumes that for any storm rainfall there will be an initial loss, Ia, which is the initial quantity of interception-depression storage and initial infiltration that must be satisfied by any rainfall before runoff occurs, "the threshold value", so the potential runoff is P-Ia. After runoff begins, the additional depth of water retained in the watershed, Fa, is less than or equal to some potential maximum retention, S. (Figure, 5.5). The hypothesis of the SCS method is that the ratios of the two actual to the two potential quantities are equal, that is,

$$Fa/S = Qe\ /(P-Ia) \tag{5.14}$$

From the continuity principle,

$$P = Qe + Ia + Fa \tag{5.15}$$

This equation is represented in Figure 5.5.

Combining (5.14) and (5.15) and solving for Qe, direct runoff, gives,

$$Qe = \frac{(P - Ia)^2}{P - Ia + S} \tag{5.16}$$

This is the basic equation for computing the depth of direct runoff from a storm by the SCS-method, and it is expressed as a mass curve in Figure 5.6. The estimation procedure for each parameter for the Sana'a basin is described below.

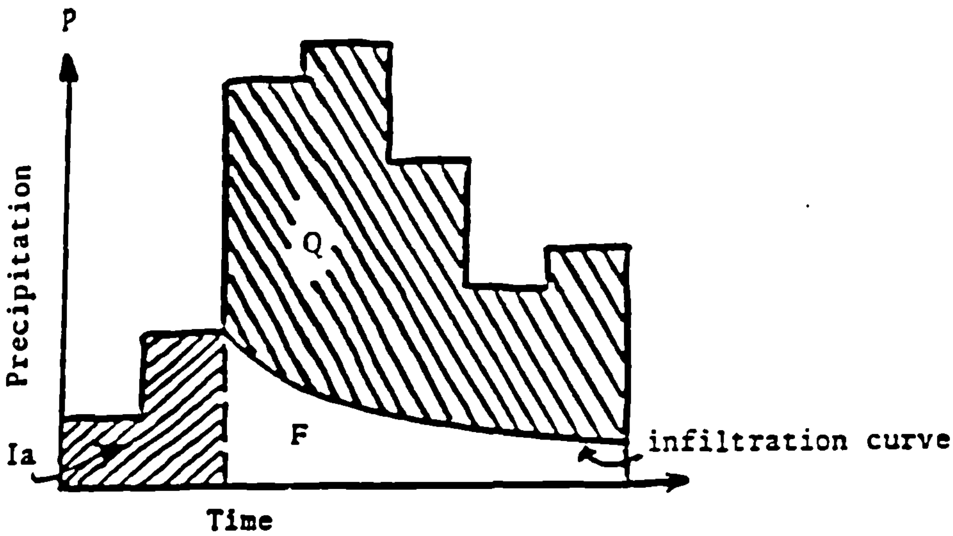


Figure 5.5 Graphical representation of the variables in the SCS method

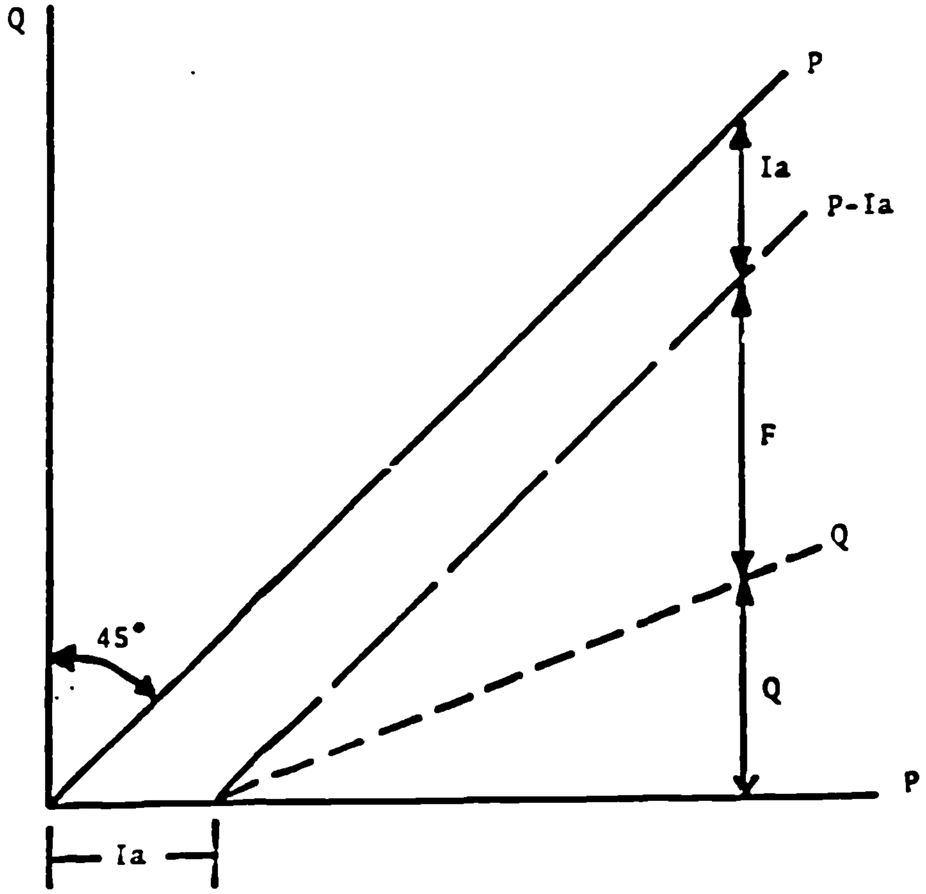


Figure 5.6 A mass-curve representation of the SCS rainfall-runoff relationship

Estimation of the soil storage potential for any wadi, S, is accomplished through use of a series of empirical curve numbers, CN, (SCS, 1972), where the storage is,

$$S = (1000/CN - 10)*25.4 \qquad (5.17)$$

25.4 is the conversion for S in millimetres.

The curve number, CN, is a function of land use, agricultural practices, crop cover, infiltration, depression storage and antecedent condition of the soil and must be estimated subjectively for each soil type. In the present study, CN values were initially selected from the USSCS tables (1972) and TSHWC, (1992) but verified using measured flow.

An empirical relation between initial loss Ia and maximum water storage potential of the soil, S, was proposed by the SCS (1972), on the basis of measured runoff from over 70 catchments in United States of America;

$$Ia = K_f * S \qquad \text{where } K_f = 0.2 \qquad (5.18)$$

TSHWC (1992), however, suggested slightly different initial loss scaling factors, (K_f) for Yemen, between 0.15 and 0.30, for each runoff characteristic zone. They argued this variation was necessary, to emphasise the hydrological differences between different ROCs. However, the S parameter in equation (5.17) which is inversely related to the curve number (CN), was originally proposed by SCS to allow for the variability of different soil types, through the fact that a higher CN value means less initial storage to be satisfied before runoff occurs. During the calibration of the present model it was found that use of different initial loss scaling factors (K_f) is required, at least for the steep rocky slopes (0.15) and for undeveloped wadi bottom (0.3).

The runoff response is strongly affected by the antecedent state of the catchment. To allow for this, SCS (1972) suggested revised CN values for "wet", "dry" and "normal" antecedent conditions;

For wet conditions,

$$CN(1) = 4.2CN(2)/(10 - 0.058CN(2)) \tag{5.19}$$

For dry conditions

$$CN(3) = 23CN(2)/(10 + 0.13CN(2)) \tag{5.20}$$

Where CN(2) is the average value for normal conditions (SCS, 1964).

The adjustment of CN values to take into account the antecedent moisture condition has been introduced to account for the effect of the preceding rainfall to the soil, using a power series which combines the effects of the preceding daily rainfall and the CN of the zone (TSHWC, 1992). This was used to modify the CN values gradually from a minimum value for dry conditions to maximum value for wet conditions, rather than jumping from CN(2) to higher or lower values as arbitrary catchment antecedent moisture thresholds were reached. The maximum value for each Roc was based on analysis of past daily rainfall in Yemen, identifying the maximum rainfall over a period of one to ten days for all stations with sufficient data (TSHWC, 1992).

5.5.4 Model Calibration:

The SCS publications provide a series of tables to assist in estimation of the appropriate curve number. The curve number values reported by TSHWC (1992) were used as initial estimates of the curve number of each runoff zone. Improved values were derived through selection of small fairly homogeneous catchment areas, with a minimum number of runoff characteristic zones, where peak flood discharges were measured in a previous study (Mosgiprovodkhoz, 1986) or during the present study. The location of the gauging sites are shown in Figure 5.1. By comparing the computed and measured floods for a succession of catchments with an increasing number of ROCs (Table 5.3), appropriate curve numbers for all zones were derived.

No measurements for a flood from a catchment with only one runoff characteristic zone were available, so the starting point was a catchment with two zones. The first catchment used was Wadi Akhwar, for the flood of 15/10/80, at Nud village (Figure 5.1) with two runoff characteristic zones; steep slopes with rock outcrops, P2 (soil 1), and undeveloped wadi bottom, A3 (soil 5). The value of curve number for A3 was estimated using SCS-soil cover procedure, with guidance from TSHWCs' estimate, and so CN value for the steep slope (soil 2) P2, was estimated from the flood.

The moderate slope P3, (soil 3) curve number was investigated using the flood measured on 15/10/80 at Thuma (Figure 5.1) in Wadi AlMhajir, whereas the curve number for the terraced valley bottom was evaluated from the flood of 15/10/80 at Ratikh in Wadi Alsir. The curve numbers for the remaining two runoff characteristic zones, P4 (soil 5) and A1 (soil 4) were estimated using floods measured during the present study in 7/4/93 at Sawan and Al Syla, respectively. A summary of the floods used for estimation of CN is given in (Table 5.3). The adopted values for CN for each zone are given in Table 5.4

Table 5.3 Summary of the floods used for estimation of CN values

site	Catchment	Area km^2	Runoff zone	Predicted flood m^3	Measured flood m^3
Nud	Akhwar	1.41	A3, (P2)	14107	14292
Thuma	Al Mhajir	13.2	A3,P2 (P3)	160525	170562
Ratikh	Al Sir	16.6	A3,P2,P3,(A2)	149378	156390
Sawan	Al Rawna	48.7	A3,P2,A2,(P4)	70611	66239
Sana'a	Wadi AlSyla	113.0	A3,P2,P3,A2, (A1)	96726	96568

() indicates the zone for which CN was estimated

Table 5.4 Adopted USSCS Curve Numbers, (dimensionless)

ROC type	CN(2) Normal catchment state	CN(1) Dry antecedent condition	CN(3) wet antecedent condition
P1 urban	97	93	98
P2 soil 1	94	87	97
P3 soil 2	88	74	95
P4 soil 5	70	60	89
A1 soil 4	55	35	74
A2 soil 6	65	45	82
A3 soil 5	70	60	89

Further verification of the rainfall-runoff model and the CN values assigned to each runoff characteristic zone was carried out by simulating the floods observed between March-August 1993 at two wadis; Wadi Dhar and Wadi alRawna.

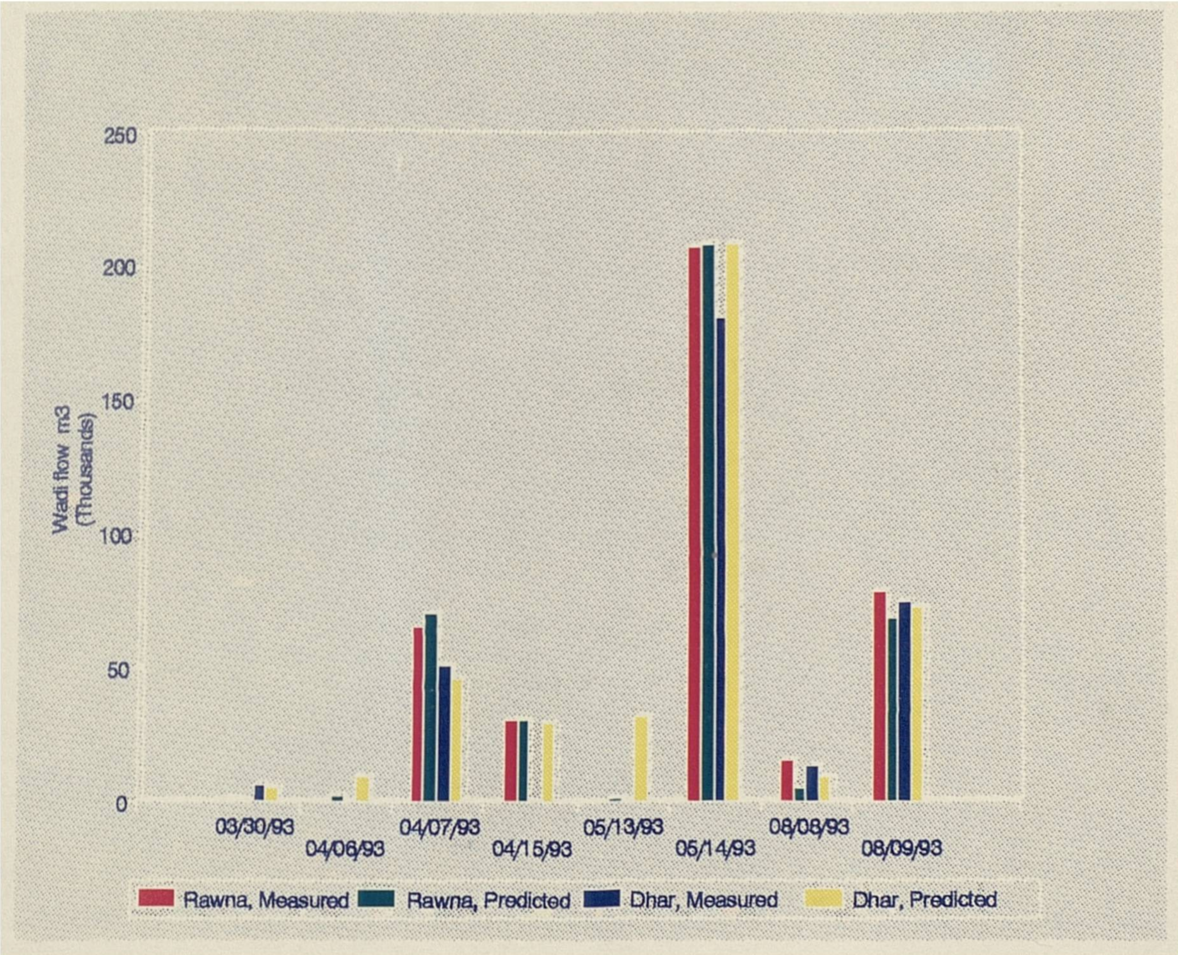


Figure 5.7 Measured and predicted Wadi flows, at Wadi Dhar and Wadi Al Rawna

Figure 5.7 shows that the number of observed runoff events was smaller than the number of events predicted by the model. This can be explained by the fact that although runoff occurred on all these days, the flood did not reach the gauging site, as confirmed by local residents in the upstream part. Another reason for the discrepancies is the distribution of the rainfall cells over the relatively large watershed area, which together with the losses along the flow channel are the two major reasons for the "partial-area contribution" phenomena (Dunne and Black, 1970). Similar problems have been reported in other studies in arid regions, even with a long record of historical data (e.g. Karnieli and Ben-Asher 1993, Ben-Asher and Humborg, 1992, William and LaSeur, 1976).

The differences between measured and predicted floods on 15.4.93 and 14.5.93 at Wadi Dhar were due to inaccuracies in the measurements, because the flood of 15.4.93 was not measured and only one of the two peak flows on 14.5.95 was measured. Nevertheless the results, shown in Figure 5.7, suggest that the model can predict a sequence of floods with sufficient accuracy.

5.5.5 Model Results

After verification, the rainfall-runoff model was used to estimate flows for 14 wadis and sub-basins over the Sana'a basin as classified in chapter 2, (Figure 2.1) and over a period 1974-1993. These wadis are listed in Table 5.5, together with the areal distribution of the runoff characteristic zones for each catchment.

Table 5.5 Areal distribution of Runoff characteristic zones for all Wadis and Sub-basin in the study area.

Catchment	Area km2	(P2) soil 1	(P3) soil2	(P4) soil5	(A1) Soil 4	(A2) Soil 6	(A3) Soil 5 Soil 7
Region A	395.1	222.5	150.2	4.7	-	-	17.7
Region B	774.5	405.8	202.3	35.0	-	-	131.4
Region C	690.5	179.0	163.9	46.6	287.0	14.0	46.6
Almahjir	80.2	48.6	10.8	4.4	-	-	16.4
Alsir	198.7	82.1	83.6	4.7	-	10.7	17.6
Asfal	217.1	59.8	96.3	5.5	-	34.6	20.9
AlRawna	76.6	24.6	32.4	4.2	-	-	15.4
Rujam	46.2	9.7	26.0	1.2	-	4.7	4.6
Dhar	321.9	65.4	46.9	16.3	-	36.4	156.9
Hamdan	29.7	12.9	6.2	1.8	-	2.0	6.8
Gyman	128.6	32.3	43.4	8.2	-	14.1	30.6
Akhwar	129.3	35.7	47.6	8.0	-	8.1	29.9
Gabir	45.4	4.2	17.1	3.6	-	6.8	13.7
Hizyz	75.2	4.2	29.9	3.3	14.9	10.6	12.3
TOTAL	3209	1187	956.6	147.5	301.9	142.0	474.2

The estimated annual average wadi flow in mm over the catchments, is illustrated in Figure 5.8. The upland wadi flow varies considerably from 3.8 mm for Wadi Hizyz, to 35.6 mm for Wadi Hamdan. This is largely a function of rainfall and highland area geomorphology. The quantities of surface flow going out of the catchment varies between 3mm for Wadi Al Syla, to 25 mm for Wadi Hamdan. This is a function of rainfall and catchment topography and geology.

Details of annual Wadi flows from upland areas and at the outlet for each wadi and sub-basin over the period 1974-1993 are given in Appendix D, with the indirect recharge estimation.

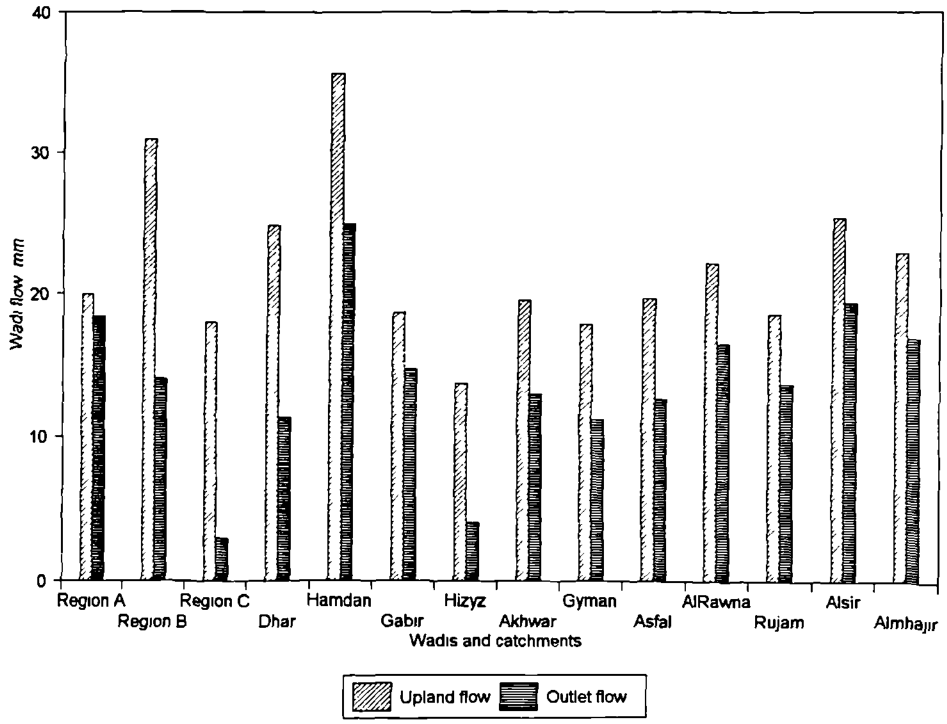


Figure 5.8 Wadi flow from upland and outlet in mm

A summary of the annual wadi flows from the uplands and at the outlet of the basin over a period of 20 years are given in Table 5.6.

Table 5.6 Summary of annual wadi flow from uplands and at outlet of Sana'a Basin.

Year	Average Rainfall MCM	Upland flows MCM	Outlet flows MCM
1974	891	77.577	23.350
1975	1220	156.000	45.885
1976	612	32.716	6.270
1977	1240	292.000	73.380
1978	630	13.541	3.804
1979	420	7.541	0.135
1980	598	40.660	12.677
1981	780	63.002	10.078
1982	975	164.000	50.298
1983	1130	253.000	78.687
1984	515	56.141	13.712
1985	582	41.872	14.717
1986	952	98.020	31.476
1987	508	7.991	1.510
1988	671	34.293	11.082
1989	462	20.532	2.114
1990	508	4.015	0.556
1991	305	3.220	0
1992	736	48.505	6.191
1993	677	66.222	18.886
Average	721	74.041	20.240

The average runoff from the upland area of the basin over the last two decades was 74 MCM/year or 8.3% of the average annual rainfall (721 MCM). The average runoff, estimated over an area of 1925 km^2 of the Sana'a basin by TSHWC (1992), was about 44 MCM. It is unknown which years were counted in that average. However, the runoff is 8.7% of average annual rainfall of 262.1 mm (504.6 MCM). Details of the areal distribution of runoff characteristic zones used by TSHWC were not given in any of the available reports.

The part of the runoff from the upland area which left the basin at the outlet in Alkharid has an annual average flow of 20 MCM/year.

6 WADI RECHARGE

6.1 Introduction

Infiltration of surface flows through the beds of ephemeral wadis is the most important mechanism of groundwater recharge to unconfined aquifers in many arid areas, because of the presence of both large volumes of highly permeable alluvium and occasional high wadi flow rates. The main character of this indirect recharge is infiltration through gravel layers, of surface water collected from a wider area than the recharge surface. The indirect recharge area can be divided into two types: On the upper (mountainous) stretches of wadis, the primary wadis within the Sana'a basin, the supply area of runoff runs parallel to the area of recharge and the recharge is into the wadi bed. In the Sana'a plain (region (C) and part of region (B), Arhab), the catchment area extends above and beyond the areal extension of the recharge area, (mountain front).

Both areas have similar factors whose combination favours the occurrence of recharge ;

(1) The availability of surface water from mountains,

(2) the thick permeable detritus of the wadi bed comprising sand, gravel and talus,

(3) The finer sediments that could impede infiltration are carried to the downstream recharge zone,

(4) the ground water table occurs deep (>10 m) below the ground surface.

Quantitative assessment of indirect wadi bed recharge is difficult because it depends on so many factors (Rushton 1988). These factors include the flow duration, runoff volume, wetted area, hydraulic gradient, soil properties, moisture content, aquifer type and depth, and land vegetation cover. These may be considered in general as stream flow characteristics, channel characteristics, and subsurface features.

With scarce data, the relative importance of each of the above influencing factors becomes crucial in evaluating any procedure to estimate wadi bed recharge successfully. This is because these factors vary from one locality to another and hence formulation of the right conceptual hydrogeological model needs to be defined first; this is described in section 6.2.

As a result of the existing data, mainly from Mosgiprovodkhoz (1986), field work during 1993, and development of the rainfall-runoff model, the flow characteristics for wadis of the Sana'a basin were interpreted, and a hydrometeorological approach based on water balance equation was used to estimate the indirect recharge. Although the water balance methods are probably the most accurate way to estimate recharge Lerner et al 1990), they commonly require a complicated set of data. By assuming the major part of the wadi recharge takes place along the wadi channel, the water balance equation was applied only over the wadi channel. This reduces the data requirement. Description of the procedure, its application and results are given in sections 6.3.

To model deterministically the recharge process, the effect of each of the factors that control recharge must be accurately known. At two wadis, AlSir and Dhar, an adequate set of data describing both the surface and the subsurface conditions was available. To reduce the uncertainty of the recharge estimation, an indirect approach for estimation of recharge by calibration of a groundwater model was used to estimate groundwater recharge through wadi beds. The groundwater models were constructed and calibrated using all the available information on the system, i.e all water balance components. The model has also been used for assessment of the importance of flow parameters which are often uncertain, by carrying out sensitivity analysis. The two essential parameters which should be measured in the field and are required in recharge calculation are: the maximum flow width (related to maximum stage by cross sectional area), which controls the opportunity for infiltration in space, and the duration of flow representing the infiltration opportunity in time. Although several previous studies (Reeder et al, 1980; Freyberg, 1983; Parissopoulos and Wheater, 1991) deal with infiltration and recharge through ephemeral wadi beds, most are either one dimensional or based on a hypothetical cross section.

The methodology, discussion and application of this technique are described in section 6.4. The results obtained from the groundwater modelling approach agreed with the results obtained by the more simple method of channel water balance. This allowed a regression model to be developed which relates the wadi flows to the recharge. Use of information from two different wadis to develop the regression equation, and the similarity of the other areas to these two wadis, made it possible to apply the regression equation over all wadis in the basin to estimate the indirect wadi bed recharge over the Sana'a basin for a period of two decades. This is described in section 6.5.

6.2 The Conceptual model of wadi bed

The wadis in the study area are remote ephemeral streams. They are normally dry, with infrequent floods generated by rainfall of high intensity and short duration. When runoff occurs, the streams will often carry large volumes of water during a flood lasting a few hours and a large proportion of the flow is observed to infiltrate the bed and banks, causing the stream to disappear before reaching its outlet. However under the right condition of a high intensity rainfall event over a relatively large part of the catchment with steep impervious slopes, the runoff can reach the lower recharge zone. The upper reach of the wadis are usually devoid of fine sediments as these are commonly washed out by flow and deposited in the downstream part, as a result of the decrease of the flood flow velocity.

The wadi deposits are normally poorly sorted with a large variation in grain size, but are predominantly coarse grained. The sediments are generally permeable, however, this permeability decreases in the downstream direction. Sediments formed within or close to the stream channel are much more coarse grained and permeable than those deposited on the flood plain. According to a schematic concept of depositional history, coarser grained materials should prevail in the upstream part of the wadi, and in older, deeper layers that were deposited during earlier, more vigorously erosive phases. Along most of the wadi, there are distinctive channel banks and channel area increases in the downstream direction. The effective channel area however varies depending upon the magnitude of the flood.

The thickness of the vadose zone varies between 10-40 m. The vadose zone thickness increases in the downstream direction where the channel bed is well above the ground water table. A saturated continuity between the stream and aquifer does not commonly exist, so accuracy in the description of the shallow aquifer may not be required in recharge estimation.

6.3 Hydrometeorological approach

6.3.1 General

The magnitude and frequency of recharge from ephemeral streams is dependent on the amount of water lost through infiltration into the wadi bed as the flood water progresses. These losses, known as the transmission losses, were computed using the rainfall-runoff model and measured floods during 1993 for Wadi Dhar. Several studies have reported transmission loss relations, for example Jordan (1977) found that transmission losses correlated well with flow volume at the upstream station. Other empirical relationships for transmission losses are given by e.g Burkham (1970), Lane et al (1971). A review of a large number of American studies of transmission losses in remote ephemeral streams was reported in WRRC (1980). More recently, Sorman and Abdulrazzak (1993), using an existing data base for a "representative" basin in Saudia Arabia, suggested several regression equations relating transmission losses and flow height, width and duration on one hand, with recharge. Good relationships between recharge and transmission losses were obtained.

Although wadi channels usually infiltrate large volumes of flood flow, the infiltrated volume should initially satisfy the soil moisture deficit and evaporation requirements before it eventually contributes toward groundwater recharge. A channel water balance approach was used to estimate both the evaporation and the deeply percolating part of the transmission losses, that escaped the evaporation and reached the shallow aquifer. The data required for unsaturated zone were compiled from available literature (Mosgiprovodkhoz, 1986). This method was applied over parts of Wadi Al Sir and Wadi Dhar.

6.3.2 Transmission Losses

Ideally, the transmission losses along the channel are quantified from flood flows measured at a pair of gauging stations, at the upstream and downstream end of the reach. With wadis similar to the one in the study area, i.e with several tributaries feeding into the main channel within the area of concern, more than two gauging sites would be required to calculate the transmission losses along the main wadi channel. For example 12 gauging sites would be required to calculate the transmission losses along Wadi Alsir alone, which is impractical.

The floods of 1993 in the Sana'a basin wadis were measured only at one site along the wadi channel in Wadis Dhar and Alrawna, at the downstream end of the reach. The upstream end of wadi channel is assumed to lie at the limit between the runoff producing zone (P2, P3 and P4, "upland area") and runoff absorbing zone (A1 ,A2 and A3 "wadi bottom"), and the flow was estimated from the rainfall-runoff model. This is justified because of the unique shape of the wadi channel, the rainfall-runoff model has been calibrated for each zone and the secondary wadi channels have been included in the calculation. It is believed that this approach provides better results than to use only 2 gauging stations over part of the main channel, and to regionalize the result over the whole channel.

The reasons are;

1) It has been observed that flooding is more frequent in the minor wadis than in the main channel, and some floods may not reach the sites of the gauging station in the main channel. A study in Negev highlands of Israel (Hillel and Tadmor, 1962) showed that recharge through

the secondary wadis is more important than in the main channel.

2) The short duration and flashy nature of the floods in the wadis may result in an error in the measured floods in two adjacent gauging sites which exceeds the transmission losses.

3) A study by Abdulrazak et al (1988) in the south-eastern wadis of Saudia Arabia showed that each part of the wadi responds differently to recharge due to soil heterogeneity.

The average curve number for the upland area CNu is computed by adjusting the average curve number for the calibrated downstream reach (watershed) CNc according to the ratio of the normal condition curve numbers for the two areas (see chapter 5);

$$CNu = (CN(2)u * CNc)/CN(2)c \qquad (6.1)$$

where CN is the average curve number, CN(2) is the normal condition curve number and the subscripts, u and c, refer to upland (ungauged) and calibrated (gauged) watersheds. Thus the normal condition curve numbers were estimated for both watersheds according to the procedure described in chapter 5, (i.e = Σ (Area of $zone_i$/total area)* $CN2_i$} where i is the number of runoff characteristic zones within the watershed). The average curve number for any day of the year was determined by the model (after accounting for the antecedent rainfall) for the calibrated watershed, and then the average curve number for the ungauged watershed was computed from equation (6.1). Knowing the runoff at the upstream end, the transmission losses were calculated from;

$$TL = Qup - Qtot \qquad (6.2)$$

where TL is transmission loss along the channel (m^3), Qup is the flow volume from the upland area (m^3) and Qtot is the flow volume at outlet of the catchment (m^3). The rainfall-runoff model provides wadi flow in volume units, which is preferable to instantaneous flow rates for ephemeral streams, because it will be difficult to estimate the time lag between the two gauging stations accurately (Lerner et al, 1990).

Results of application of this equation to Wadi Dhar and Wadi Alsir are given in Table 6.1. Although Qtot for Wadi Dhar was measured during the observed flows of 1993, for Wadi Alsir both flows, Qup and Qtot, were estimated from the rainfall-runoff model. The additional application of the equation to Wadi Alsir was due to; (1) apply the method to more than one site, (2) to test the capability of the rainfall-runoff model to predict the difference within one catchment, and (3) the availability of recharge estimation for this wadi by another independent method.

Table 6.1 Wadi flow volume from upland area (Qup), at the outlet (Qtot) and Transmission losses (TL) for two Wadis.

Date	Dhar			Al Sir		
	Qup m^3	Qtot m^3	TL m^3	Qup m^3	Qtot m^3	TL m^3
30.3.93	12244	5515	6729	64085	15429	48656
06.4.93	18629	9698	8931	143983	61008	82975
07.4.93	63748	46448	17300	638625	449439	189186
15.4.93	45070	29672	15398	399897	256796	143101
13.5.93	48639	31696	16943	129057	51337	77720
14.5.93	231139	209450	21689	1338289	1096811	241478
08.8.93	16837	9620	7217	222437	131042	91395
09.8.93	93842	73213	20629	630844	428107	202737

6.3.3 Calculation of Deep percolation

Before deep percolation or recharge to the shallow groundwater aquifer can be estimated from the transmission losses, soil moisture deficit and evaporation must be quantified.

Evaporation from wadi channel beds and water surface is difficult to estimate, or even impossible (Lloyd, 1986), and only a few measurements have been reported in the literature. Sorey and Matlock (1969) carried out some small scale lysimeter experiments on evaporation from stream bed sands. Over 19 days, total evaporation ranged from 5 mm in a very coarse sand to 26 mm in a medium sand. In Saudi Arabia, evaporation of 2% of the total runoff has been reported (FAO, 1981). Hillel and Tadmor (1962) in describing the water regime over the central Negev, they reported evapotranspiration to be 6 mm/day.

Evaporation from the river surface may be estimated by Penman's open water method (Doorenbos and Pruitt, 1977). However, evaporation from ephemeral river beds, which becomes increasingly important as frequency of flooding decreases, is still difficult to estimate, as the availability of moisture in the soil and the type of soil become controlling factors in the process. Soil moisture measurements are not available prior to each rainfall event and must be estimated. In the present study, actual evaporation was estimated using a daily moisture counting procedure for the soil type in the wadi channel.

A model which describes both the evaporation and the soil moisture deficit was developed, based on a simple daily water balance equation over the wadi channel. The description of the model is given first, then application of the method is described.

6.3.3.1 Channel water balance model

The unsaturated zone is subdivided in two portions, the upper portion acts as a reservoir, in which a moisture deficit with respect to field capacity may exist due to evaporation. The remaining portion acts as a linear reservoir and is assumed to be at permanent field capacity. Rainfall and the transmission losses minus evaporation replenish the upper reservoir of the unsaturated zone. The excess moisture above field capacity is assumed to drain out of the upper reservoir on a daily basis, thus escaping evaporation.

The components of the daily water balance equation in the proposed model, which uses a simple 'bucket' approach over the wadi channel, depends on the type of rainfall.

The first case is rainfall which does not generate runoff and in this case, only the rainfall which falls over the wadi channel will infiltrate into the soil, and the soil storage changes accordingly;

$$D = P - Et - Zd\theta \qquad \text{(no runoff from upland)} \qquad (6.3)$$

When rainfall is accompanied by runoff from the upland area, the transmission losses over wadi channel are used instead of the rainfall;

$$D = P + TL - Et - Zd\theta \quad \text{(with runoff from upland)} \quad (6.4)$$

where

P is the precipitation,

TL is the transmission losses over wadi channel,

Et is the actual evaporation,

D is the deep percolation through the lower boundary of the soil profile,

and, $Zd\theta$ is the change of soil water storage and is confined between the upper and lower boundaries of a one dimensional vertical system. All water balance equation components have units of length (L), and they are illustrated in Figure 6.1.

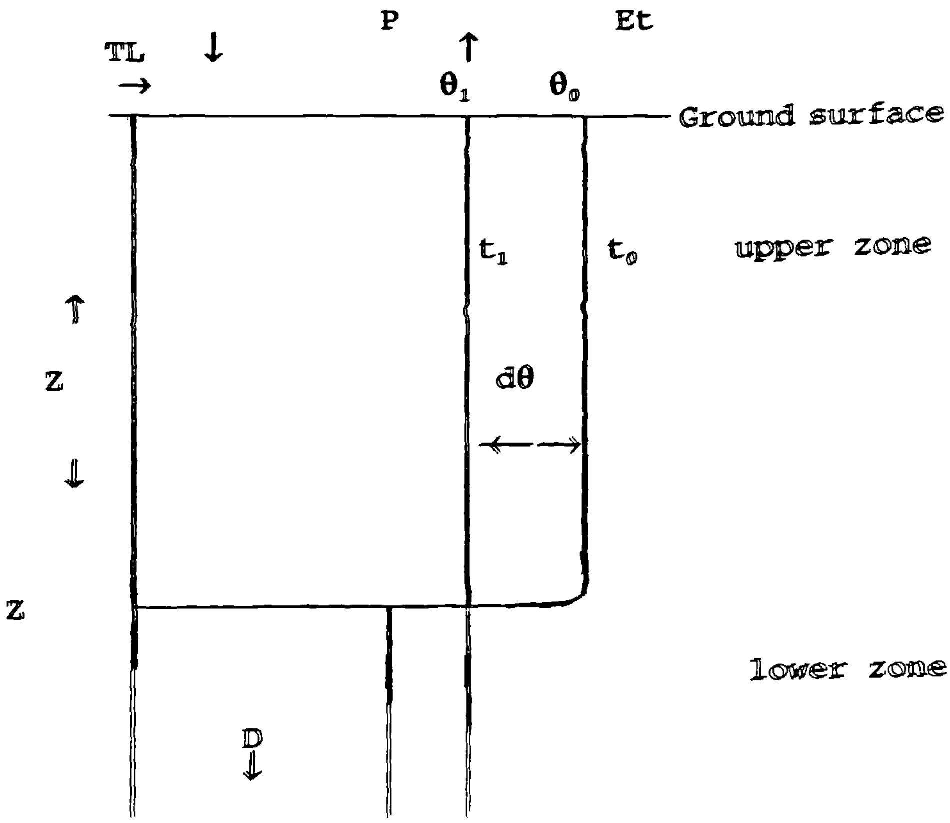


Figure 6.1 Schematic representation of water balance

6.3.3.2 Operation of the channel water balance

The model proceeds by adding daily rainfall or transmission losses over the wadi channel while removing actual evaporation from the soil moisture storage. The soil moisture storage at the beginning of the first rainy season is the product of the measured residual water content (Mosgiprovodkhoz, 1986) and the depth of the upper zone, Z. The value of Z is taken equal to 500 mm. Below this depth the evaporation is considered insignificant (FAO, 1981) and the water percolating deeper becomes recharge.

Typical values of the soil properties for the wadi channels were compiled from dam site investigations by Selhozpromexport (1987) as;

field capacity 0.18
wilting point 0.08
maximum temporary water storage = (0.18-0.08) = 0.1
maximum moisture storage (MAXST) = 0.1 * 500 = 50 mm

The channel water balance equation was applied over the same area used to model the stream recharge in the groundwater modelling approach; 21500 m^2 and 450000 m^2 for Wadi Dhar and Wadi alSir, respectively.

The actual daily evaporation was calculated from the Penman-Monteith equation, using the computed soil moisture storage, and assuming an exponential decline in evaporation as soil moisture decreases from field capacity. After deducting actual evaporation, the soil moisture storage was compared with the maximum value, and excess moisture percolates to the lower unsaturated zone, becoming recharge to the wadi alluvium.

The mathematical structure of the operation of the model is as follows;

(1) The rainfall (P) or/and transmission loss (TL) on the ith day is added to (Si), the soil moisture storage at the start of the ith day. Thus the revised uniform moisture in the upper reservoir (S'i) will be;

$$S'i = Si + TL \qquad (6.5)$$

or

$$S'i = Si + P \qquad (6.6)$$

(2) The daily actual evaporation on the ith day (Eti) is calculated from the soil moisture storage and the Penman-Monteith equation.

$$Eti = Eto \qquad \text{if } S'i >= MAXST \qquad (6.7)$$

or

$$Eti = Eto * S'i/MAXST \qquad \text{if } S'i < MAXST \qquad (6.8)$$

As the soil moisture decreases from the field capacity (MAXST), the actual evaporation declines from the potential evaporation and this decline is assumed to be exponential. The coefficient used was the soil moisture at the ith day, S'i, divided by MAXST.

(3) The moisture storage S"i after deducting the amount for actual evaporation will be

$$S''i = S'i - Eti \qquad (6.9)$$

(4) Deep percolation Ri is the excess of moisture above MAXST

$$Ri = S''i - MAXST \qquad \text{if } S''i > MAXST \qquad (6.10)$$

or

$$Ri = 0 \qquad \text{if } S''i <= MAXST \qquad (6.11)$$

(5) If Ri evaluated at step (5) is not zero, the soil moisture S""i in the upper reservoir equals MAXST, otherwise it equals S"i

$$S''''i = MAXST \qquad \text{if } Ri > 0 \tag{6.12}$$

or

$$S''''i = S''i \qquad \text{if } Ri = 0 \tag{6.13}$$

and calculation is repeated for the subsequent day.

The spreadsheet used to calculate the water balances for sections of two wadis, Wadi Dhar and Wadi AlSir is given in Appendix D. The results are given in Table 6.2, together with results of groundwater recharge for the same wadis, calculated using a groundwater modelling technique (section 6.4), which acted as an independent check to validate the results obtained by the channel water balance method.

Table 6.2 Recharge as determined from surface model and groundwater model at two wadis.

date	Wadi	Dhar	Wadi	Al Sir
	Channel W.B. m^3	MODFLOW m^3	Channel W.B. m^3	MODFLOW m^3
30.3.93	2265	2888	22122	16200
6.4.93	3715		60174	
7.4.93	8080	8204	148428	204830
15.4.93	6826	6419	109374	117480
13.5.93	7249		50220	
14.5.93	10128	18176	190536	255660
8.8.93	2348	4203	55863	53000
9.8.93	9588	8200	156423	157000
Total	50199	48091	793144	804170

The difference in the temporal distribution of recharge between the two methods was attributed to the "Partial area contribution" (chapter 5). For the groundwater modelling, only floods measured at the gauging site (the lower limit of the modelled part of the aquifer) were used, but all floods estimated by rainfall-runoff model were used in the calculation of the transmission losses and the recharge from the water balance. This implies that using the rainfall-runoff model for estimation of the upland area flow is better in recharge calculations than using two gauging stations on the main wadi channel. The MODFLOW results reflect aquifer responses to the recharge pulses, and as described by the sensitivity analysis (section 6.5), the temporal distribution of flow has minimal effect on cumulative infiltration.

6.4 Numerical simulation approach

6.4.1 Digital model of the aquifers

Digital models of the shallow unconfined alluvial aquifers in Wadi Dhar and Wadi alSir were constructed in order to study the groundwater recharge along the wadis. The models used the USGS MODFLOW package (McDonald and Harbaugh, 1988), which is a transient, finite difference groundwater flow model, with a range of options capable of representing the essential features of the water balance and groundwater flow in the study area. The Stream-flow routing package was developed to account for the amount of flow in streams and to simulate the interaction between surface and groundwater. However, it is not a true surface-water flow model (i.e does not include a time function for routing flows), but rather an accounting program that tracks the flow in one or more streams which interact with aquifer, and limits the amount of infiltration to the water available in the stream. The package calculates stream stage for a reach using the Manning formula. As required by the Stream-flow routing Package, only the sections of the alluvial aquifer that have no hydraulic connection with the underlying formation have been simulated, thus only single layered models were required. The accuracy of the model results are to a large extent dependent on the size of the model cells, the time intervals used in the simulations, and the closure criteria for completing the iteration cycle in the modular model (McDonald and Harbaugh, 1988). Details on its mathematical formulation are given in Prudic (1988).

6.4.1.1 Model domain

Only the part of the alluvial aquifer without hydraulic connection with the underlying formation has been simulated as required by the SFRP (Stream-flow routing package) using all geological, hydrogeological and hydrochemical information available for the modelled area. These data consist of well-logs, vertical electrical sounding results, topographic maps, soil maps, geological maps, hydraulic properties of the channel, unsaturated zone and the shallow aquifer from feasibility study for dams at site for each wadi, Dam numbers 4 and 17, Mosgiprovodkhoz (1986), Selhozpromexport (1987), Survey Authority (1986), and detailed well inventory of the present withdrawal from the shallow aquifer (SAWAS, pers. comm. 1993), and recent irrigation return flow estimated from simulating of the unsaturated zone (Chapter 4).

The model domain developed for Wadi Dhar covers the upper part of the alluvial aquifer. The domain has been discretized into 42 columns and 15 rows in a regular grid, orientated east-west and comprising approximately 504 nodes. Rows line are 25 m apart and nodal spacing along the wadi channel is 50 m apart. The grid spacing was found to produce a good resolution for the present problem. An irregular grid spacing was used for the model domain in Wadi alSir, with 28 rows and 35 columns. Small cells were used along the wadi channel in order to obtain accurate results for the study of recharge, and large cells were used at the boundaries of the wadi. The locations of the wadis can be seen in Figure 5.1 and a summary of information of the modelled areas is presented in Figures 6.2 and 6.3.

6.4.1.2 Aquifer geometry and hydraulic properties

For both wadis, the aquifer total thickness increases gradually in the downstream direction. For Wadi Dhar, the thickness at the upstream limit of the modelled area is 18.7 m, and it increases gradually toward the eastern end of the modelled area to reach 57 m. For Wadi AlSir, the thickness increases from 63.2 m to 94 m at the limit of the modelled area in the downstream direction. The extent of the aquifer was read from the available geological maps (Mosgiprovodkhoz, 1986) and it clearly coincides with the wadi bottom, as can be seen from the 1:50,000 topographic maps, which were used to derive the elevations of the upper surface of the aquifer. Tables for elevation of top and base of aquifer for each cell are given in Appendix D.

The aquifer over the modelled area is unconfined. The hydraulic parameters of the Quaternary deposits aquifer were described in detail in Chapter 3. A feasibility study carried out by the Russian (Selhozpromexport, 1987) for Dam construction (No. 4 and 17) at Souq Bayt Na'am and Bani Hushish near the modelled area in Wadi Dhar and Alsir, respectively, reported hydraulic conductivity of the alluvial material as 1.5 m/day.

After the calibration, the hydraulic conductivity at Wadi Dhar was 0.86 m/day and for Wadi alSir varies between 0.25 and 0.7 m/day. The adjusted highest values are along the wadi channel.

With respect to the water table recovery and recharge "ground-water regime analysis", Mosgiprovodkhoz (1986) attempted to estimate the infiltration coefficient of rainfall (rainfall seepage recharge coefficient) over the alluvial aquifer at the upper reach of Wadi Dhar, using an equation similar to;

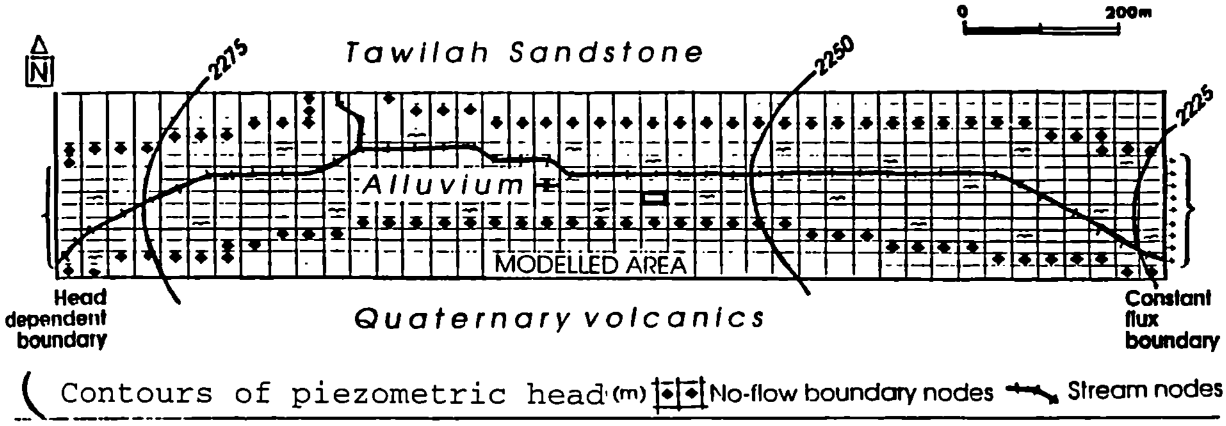
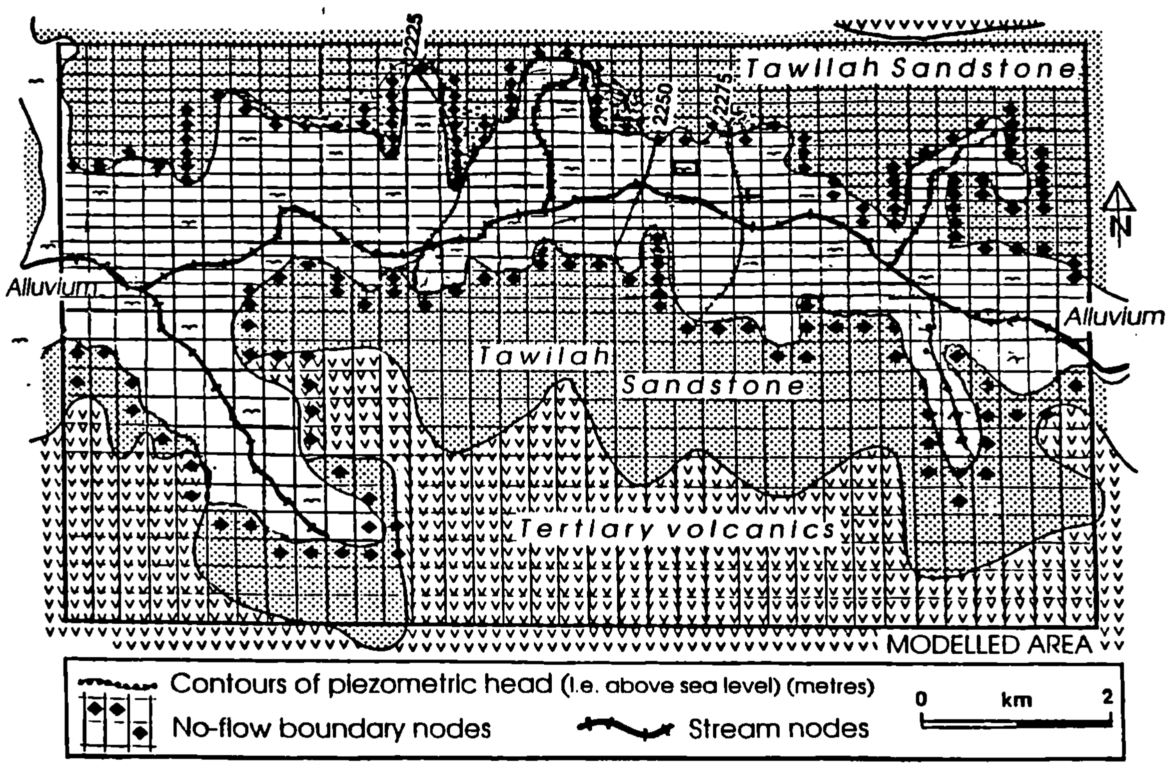


Figure 6.2 Modelled area of Wadi Dhar



Figures 6.3 Modelled area of Wadi Alsir

$$k = 1000\ Sy\ dh/p \tag{6.14}$$

where

k is an infiltration coefficient of rainfall

Sy specific yield (effective porosity)

dh change is groundwater level, m and

p rainfall during the design period in mm

The value used by the Russians for Sy varies between 0.05 at well (502) and 0.08 (at well 511a). Although they did not report the origin of these values, they seem reasonable for alluvial materials.

During the calibration of the present model, and using the period after the rainy season, the effective porosity has been determined as 0.11 for wadi Dhar and 0.06 to 0.08 for Wadi alSir.

6.4.1.3 Boundary Conditions

The boundaries of the alluvial aquifer at the upstream end was simulated with constant flux. The downstream boundary of the modelled area, which is defined by the area where the alluvial aquifer becomes hydraulically connected to the Cretaceous Sandstone, was simulated with a head dependent flux. The physical limits of the alluvial aquifer at the sides of the wadi bottom are the steep slopes of mountains surrounding the wadi on both sides. "No-flow" boundaries were used to simulate these conditions, as neither can groundwater flow be expected from the bedrock aquifer into the alluvial nor vice versa. This is because the groundwater level in the mountain is below the alluvial aquifer and the permeability of the non-fractured rock is far lower than the alluvial aquifer except along faults. The piezometric maps (Mosgiprovodkhoz, 1986), Figures 6.2 and 6.3 indicate the direction of the groundwater flow towards the main wadi channel and then in a downstream direction.

6.4.1.3.1 Abstraction

Raw data from a recent well inventory over the reach of Wadi Dhar as well as Wadi AlSir, were obtained from SAWS (person. comm. 1993) and used to estimate the abstraction from the shallow alluvial aquifer. 5 dugwells were located within the modelled area in Wadi Dhar and 18 dugwells in Wadi alSir. The discharges of these wells and their locations are given in Appendix D.

6.4.1.3.2 Recharge

As the modelled areas are cultivated mainly with qat and/or grapes, the initial estimate of direct recharge was computed according to the percentage of irrigation return of the total applied water estimated for these crops in chapter 4. However, as neither the exact irrigated area is known nor the cropping pattern, information from the well inventory and the number of existing wells was used to define the abstraction and thus the return to the shallow aquifer. The final figures, after calibration, for direct recharge (irrigation return) over the modelled area were 129 m^3/day for Wadi Dhar and 508 m^3/day for Wadi AlSir during the period of the simulation.

6.4.2 Model calibration and recharge estimation

Calibration was achieved in two steps.

6.4.2.1 Steady state calibration

This calibration was focused on re-creation of the general patterns of groundwater flow described in the conceptual model and similar to the most recent, complete piezometric map of 1985, (Mosgiprovodkhoz, 1986) which seems to represent approximately average conditions. Using water level measurements from the present study, the depths to water in March 1993 were combined with the 1985 map to produce piezometric maps for March 1993, used for both the steady state calibration and as initial conditions for the transient modelling. (Figs. 6.2 and 6.3)

This is justified by the observation that during the dry cold season (November-February), a stable water level was observed in dug-well 502 (Wadi Dhar) in the period 1982-1985, (Mosgiprovodkhoz, 1986). In fact, even during the observations 1993, water levels in the observation wells in Wadi Dhar showed no fluctuations during July and only started to rise after the flood of 9 August. Information from the well inventory carried out by SAWAS (pers. comm., 1993) and questioning of locals in Wadi Dhar indicated that farmers do not use their shallow wells during July, due to the limited depth of the dug wells, and use them only when the water level rises. As the water level falls, they return to the deep boreholes. Similarly for Wadi alSir dugwells are used only during the rainy seasons, however for Wadi alSir this means March-September, probably because of the depth of the dug wells and the size of the alluvial aquifer.

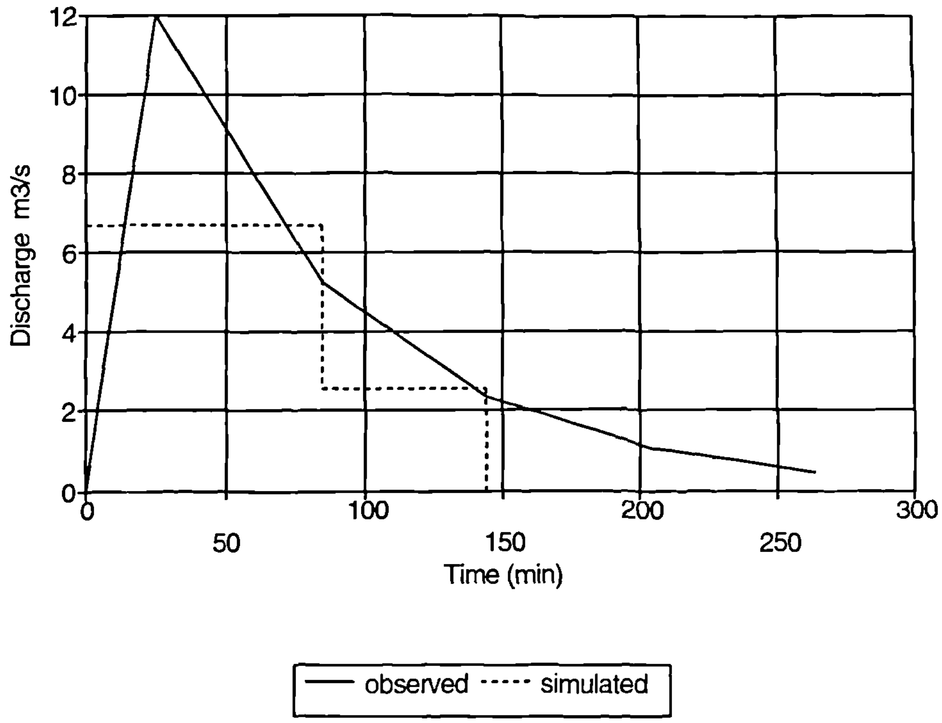
The transmissivity, boundary conditions, and average recharge values were adjusted within reasonable constraints so that the model would reproduce the groundwater levels in March 1993.

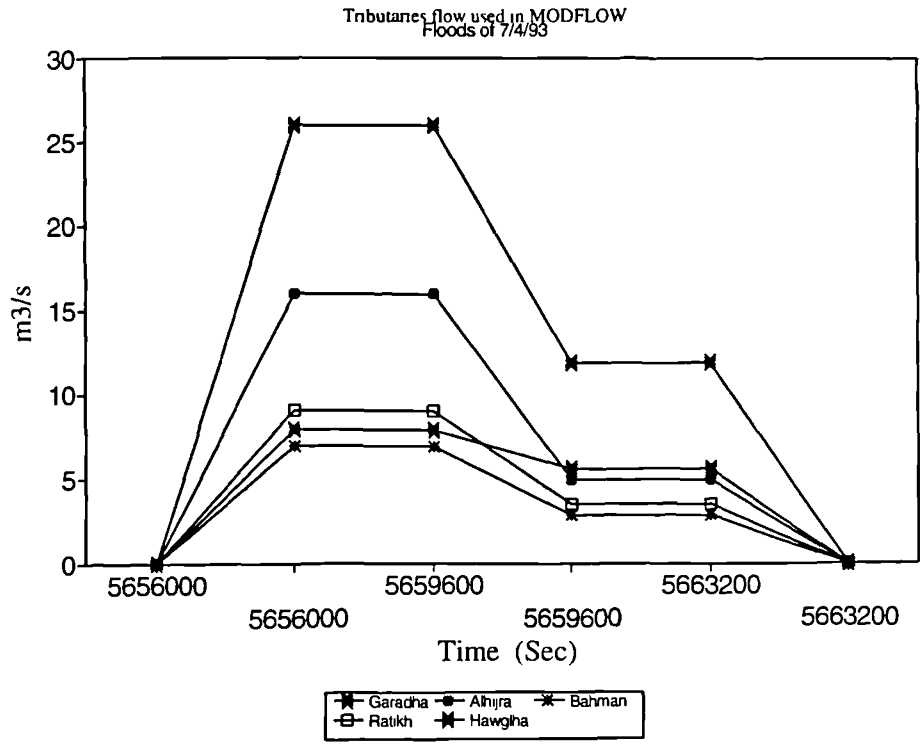
6.4.2.2 Transient calibration

Using the steady state calibration as the starting point, the transient calibration was performed over the period of the first rainy season (April-May), followed by a dry season with no storms until 8 August 1993, thus using both the recovery period during the rainy season and the recession during the subsequent dry season.

The four floods which occurred during the first rainy season, on 30 March, 7 April, 15 April and 14 May 1993, were all simulated for both sites. For Wadi Dhar, flood flows measured in 1993 were used. For Wadi alSir, the rainfall-runoff model was used to estimate the volume of runoff. Detailed information on flood volume estimation for each tributary (5 tributaries) is given in Appendix D. The hydrographs for the first rainy season of 1993 were constructed using information about the duration of the flood from local residents, and a relationship between the peak discharge and the shape of the flood hydrograph, developed by Mosgiprovodkhoz (1986) for the western wadis of Yemen (Chapter 5). Examples of flood hydrographs for the two wadis for the flood on 7/4//95 used in the Stream-flow routing Package in MODFLOW are shown in Figure 6.4. Other hydrographs are given in Appendix D.

The boundary conditions, aquifer thickness and hydraulic conductivity values from the steady state calibration were not changed during the transient calibration.





'igure 6.4 Simulated hydrographs for floods of 7/4/95
.t, (A) Wadi Dhar (B) Wadi Alsir.

The values of the stream-bed hydraulic conductance, which represents the degree of hydraulic connectivity between stream and aquifer, and the specific yield of the alluvium were adjusted simultaneously, by a trial and error process, until the observed water level fluctuations in the wells during and after the floods were reproduced.

The period between 14.5.93 and 8.8.93 is important in the estimation of the specific yield. During this period, there were no storms, so the natural decline in groundwater levels depends only on the specific yield, which was adjusted during calibration, assuming that the transmissivity determined by the steady state fitting is correct (Besbes et al 1978). The measured water levels during the dry period allow both recharge and porosity to be computed. The value of the effective porosity is important, because if the effective porosity is underestimated, a good fit can be obtained by underestimating the recharge by a proportionate amount.

The process of transient calibration included the following steps:

(1) estimation of the specific yield. The starting values were 8% and 6% for Wadi Dhar and Wadi Alsir respectively, based on analysis of past hydrographs (Mosgiprovodkhoz, 1986);

(2) assigning values to stream-bed hydraulic conductance, derived initially from calculation of the volume of water under the recharge mound;

(3) running the model in transient mode from 30 March to 8 August 1993, using measured or simulated flood data;

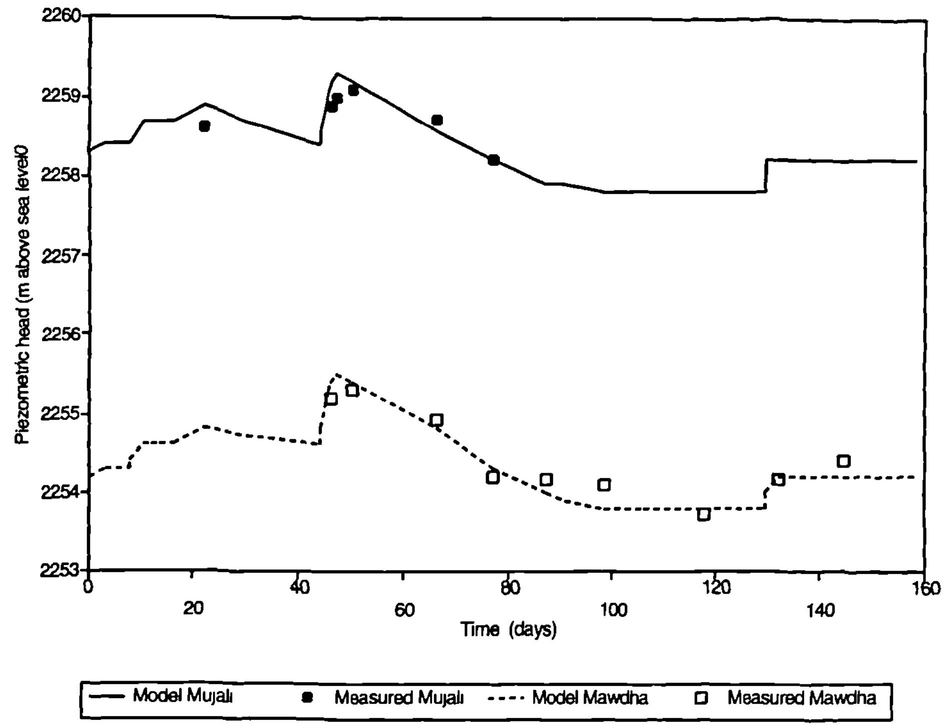


Figure 6.5 Measured and Simulated Water levels, Wadi Dhar

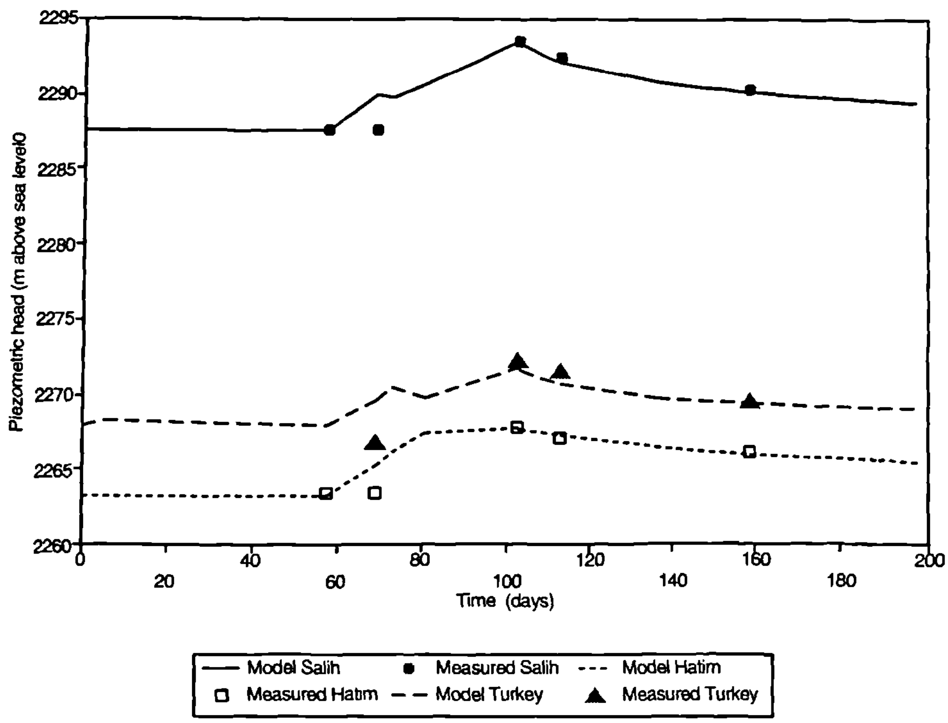


Figure 6.6 Measured and Simulated water level, Wadi Alsir

(4) comparison of the simulated and observed groundwater hydrographs, and repetition of steps (1) to (3) until a satisfactory simulation was achieved.

This approach could be very time consuming in the case of a very long series of floods.

Figures 6.5 and 6.6 show the computed and observed heads at the end of the calibration. Although the agreement is good for both models, the results for Wadi Dhar are a better fit and were obtained more easily than those for Wadi Alsir. This is attributed to the fact that the Stream flow package assumes that leakage from the stream to the aquifer is instantaneous, which is more realistic for Wadi Dhar where the unsaturated zone is thinner than Wadi Alsir. The results imply that the assumption of instantaneous recharge is reasonable when the thickness of the unsaturated zone between stream and aquifer is small.

The calculated volumes of recharge for the modelled areas compared well with the estimates of recharge computed from channel water balance for the modelled reaches and over the same period of time (section 6.4.2). Both results are given in Table 6.2

6.4.3 Sensitivity analysis

The aim of the sensitivity analysis was to assess the significance of some parameters, whose values are commonly uncertain. The analyses were based on the flood on 7 April 1993 in Wadi Dhar.

The ephemeral flows in minor streams in arid areas are characterised by a rapid rise in the stream stage and a very short duration, commonly only a few hours. Consequently, simulation of the flood requires the use of extremely short time steps in the stream-flow routing package. This is time consuming and tedious work, because each stream reach has to be entered for every time period.

Therefore the first parameter tested was the temporal distribution of the flood intensity. This was done by holding the volume (35640 m^3) and the duration of the flood (150 minutes) constant, but changing the distribution of the flood, as illustrated by Fig.6.7. In case A, two time intervals were used, of 90 minutes with a flood discharge of 5 m^3/s, followed by 60 minutes at 2.4 m^3/s. In case B, the time intervals were divided by two, so the flood discharge for each time interval became 7.5 m^3/s (for 45 mins), 2.5 m^3/s (for 45 mins), 3.6 m^3/s (for 30 mins) and 1.2 m^3/s (for 30 mins). The results, in Table 6.3, show a difference between the cumulative infiltration from the two cases of only 0.6%, which indicates that inaccuracies in the temporal distribution of the flood intensity do not affect the model's estimate of cumulative infiltration.

The second parameter tested was the flood discharge rate, which was estimated from observations of stream stage in surveyed cross sections using Manning's formula. One of the uncertainties of this method is the estimation of the roughness coefficient, Manning's n. For the modelling, the duration of the flood was held constant at 150 mins, and the discharges used for case A, 5 m^3/s for 90 mins and 2.4 m^3/s for 60 mins, were multiplied by a factor of 1.25 for case C, as shown in Fig. 6.7. The difference of the recharge volume for the two cases is less than 2%, as shown in Table 6.3, far less than the 25% increase in the rate of flood discharge. Therefore, the cumulative infiltration can be considered to be relatively insensitive to the magnitude of flood event.

The third test concerned the duration of the flood. An increase in the flood duration of 25% caused an increase in recharge volume of 23 %, as shown in Table 6.3. This agrees with the conclusions of Parissopoulos and Wheater (1991) for a hypothetical wadi, and clearly indicates the strong influence on cumulative infiltration of the infiltration opportunity in time.

Table 6.3 Results of sensitivity analyses

Parameter	Multiplication Factor	Change in recharge volume	Change in heads (m)
Distribution of flood intensity		+ 0.6%	no change
Discharge	1.25	+ 1.7%	0.1
Duration	1.25	+ 23.0%	+0.1 to +0.2

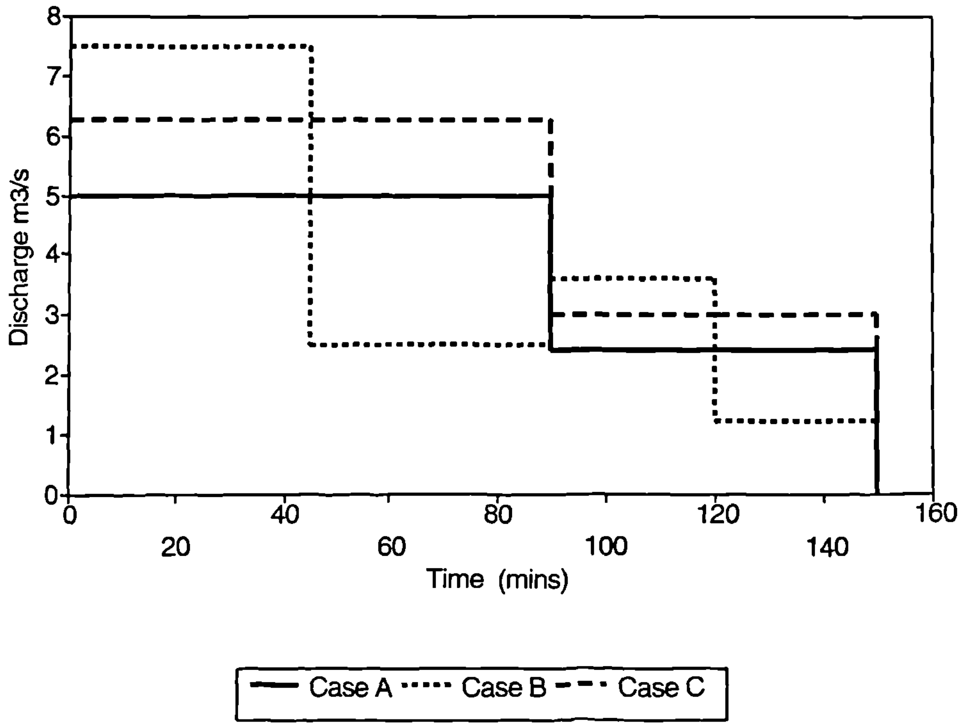


Figure 6.7 Flood discharge, 7/4/93 Wadi Dhar

6.5 Regression Model and recharge

In arid and semi-arid areas, the most important factors affecting recharge of the area underlying an ephemeral stream are the flow duration and flow volume. The stream cross section and the wetted perimeter may also be important factors, however they are more or less implied by the flow volume. Data from Mosgiprovodkhoz (1986) and Selhozpromexport (1987), observations and questioning of locals all confirm that the duration of most floods are of 2 to 3 hours, for 2 or 3 consecutive days. Daily rainfall data records over 20 years support the occurrence of rainy days over 3 to 4 consecutive rainy days (chapter 2). So it is reasonable to assume that the only variable input into the system is streamflow volume. Moreover, the recharge amount estimated for two wadis during 1993, using deterministical model in which the effect of all factors that may affect wadi recharge was considered, agrees with the amount of recharge estimated using a daily channel water balance method.

From the results above and to predict, with reasonable accuracy, the recharge rates from other wadis, a regression model was developed between the physically related wadi flows from the upland area (Qup), wadi flows at the outlet of the catchment (Qtot), and groundwater recharge estimated by the channel water balance approach for Wadis Dhar and Alsir. The sample data of the independent variables and the dependent variables are given in Table 6.4 and were used to compute the coefficients of the analytical model by the method of least squares. The regression model is shown in figure 6.8 and its equation is:

$$R = -3455.35 + (0.964435 * Qup) - (0.93818 * Qtot) \quad (6.15)$$

where

R is recharge ,m^3

Qup is runoff from upland area, m^3

Qtot is runoff at the station or outlet, m^3

The high value of the coefficient of determination (r^2 = 0.99) and the small standard error of the estimate (6327 m^3) indicate the strong relationships between the variables used in the equation and its capability to predict groundwater recharge for other wadis, provided that the values of Qup and Qtot are available.

Table 6.4 Variables used to develop the regression equations for two wadis; Qup, Qtot and recharge.

Wadi	Date	Upland runoff m3	Outlet runoff m3	Wadi Recharge m3	By Eqn. (6.15) m3	By Eqn. (6.16) m3
Alsir	30/3/93	64085	15429	29496	43875	28463
	6/4/93	143983	61008	80232	78170	46143
	7/4/93	638625	449439	197904	190802	155598
	15/4/93	399897	256796	145833	141298	102772
	13/5/93	129057	51337	66960	72848	42840
	14/5/93	1338289	1096811	254048	258231	31042
	8/8/93	222437	131042	74484	88129	63504
	9/8/93	630844	428107	208564	203311	153877
Dhar	30/3/93	12244	5515	4795	3179	16992
	6/4/93	18629	9698	7867	5412	18405
	7/4/93	63748	46448	17110	14449	28389
	15/4/93	43295	29672	13447	10462	23863
	13/5/93	46202	31696	14193	11366	24506
	14/5/93	231139	209450	21448	22961	65429
	8/8/93	16837	9620	4972	3757	18008
	9/8/93	93842	73213	20304	18362	35048
TOTAL				1161603	1166618	1134265

Using two variables for wadi flows, Qup and Qtot, and estimation of their values from the rainfall-runoff model implied that catchment moisture conditions, which affect ephemeral wadi recharge had been included in the recharge estimation. This can be illustrated by the following exercise, carried out to estimate the recharge from the lower stretches of the primary wadis.

There are 11 primary wadis (Chapter 2), which discharge their runoff Qtot into Sana'a plain. To quantify the recharge from the lower stretches of these wadis, a regression equation between Qup and recharge was developed using the same data given in Table 6.4. This is because Qtot from the upper stretch of wadi is also Qup for the lower stretch of wadi, and apart from the less frequency of floods reaching the lower stretch of wadi, the conditions are almost the same, (section 6.2). Only one variable was used to develop the relation, because Qtot for the lower stretches (i.e the part of the flow that reached the main channel of the Basin, alSyla) is unknown. The equation is;

$$\text{Recharge} = 14283 + .221281 * \text{Qup} \qquad (6.16)$$

$r^2 = 0.87$

$SEE = 14283\ m^3$

Both the coefficient of determination and the standard error of estimate indicate less reliable predictions by this regression model than the first regression model. It was found equation (6.16) provides accurate total recharge, however, it is less accurate for an event-based recharge (Table 6.4). This is because the two variable equation included the moisture content of the catchment, but the single variable equation included only runoff volume. The calculated wadi recharge from the regression model and from the channel water balance are illustrated in Figure 6.8

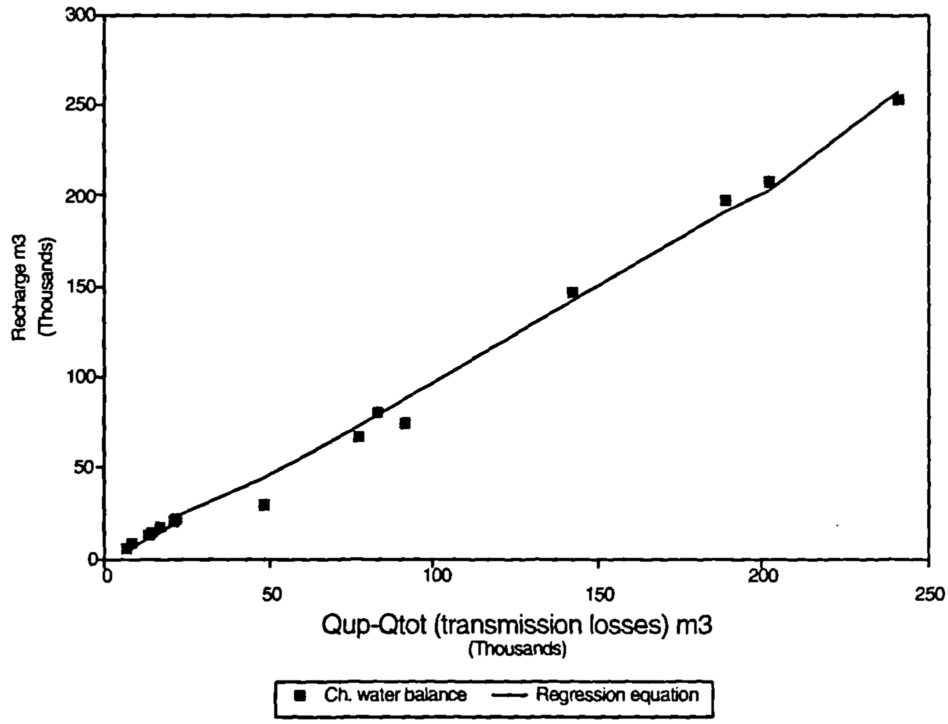


Figure 6.8 Calculated (CWB) and predicted recharge from regression model during 1993

The data required for the rainfall runoff model are geomorphological information and daily rainfall (chapter 5). The regression models allow extrapolation of the groundwater recharge for a period of 20 years and for all wadis in Sana'a basin. Detailed results, including Qup and Qtot and groundwater recharge for all wadis, over 20 years (1974-1993), are given in Appendix D

The annual indirect recharge over the whole basin during the period 1974-1993, together with runoff from upland area are given in Table 6.5 and illustrated in Figure 6.9.

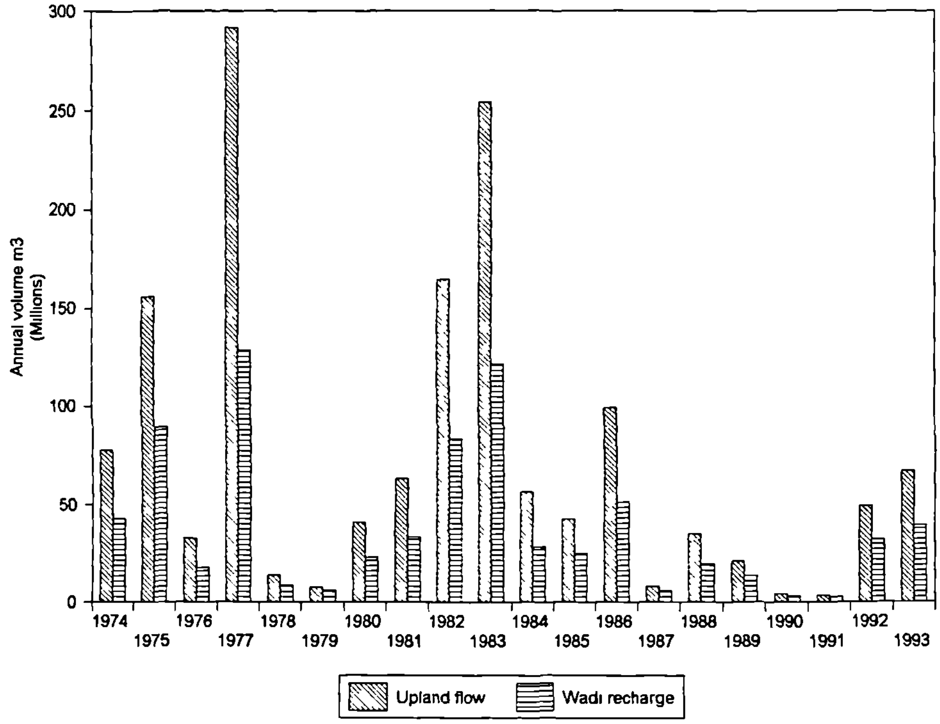


Figure 6.9 Annual upland flow and indirect recharge over the basin

Table 6.5 Indirect recharge over Sana'a Basin

Year	Upland runoff MCM	Wadi Recharge MCM
1974	77.576	42.574
1975	155.891	89.397
1976	32.716	17.789
1977	291.810	129.000
1978	13.541	8.738
1979	7.541	6.051
1980	40.660	2.314
1981	63.002	33.138
1982	163.777	82.908
1983	253.495	120.000
1984	56.141	27.746
1985	41.872	24.496
1986	98.020	50.741
1987	7.991	5.528
1988	34.293	19.323
1989	20.532	13.433
1990	4.015	3.048
1991	3.22	2.853
1992	48.505	31.505
1993	66.222	38.895
Average	74.040	38.520

The annual average wadi recharge over the basin over the last two decades was 38.5 MCM/year of which 3 MCM is groundwater recharge over the lower stretches of the primary wadis.

The wadi recharge is more related to runoff events rather than annual rainfall. The annual average recharge is 60% of the average annual runoff from the upland area and 4.5% of the average annual rainfall. More detailed results and distribution of wadi recharge between aquifers are described in chapter 9.

7 URBAN RECHARGE

7.1 Introduction

Urbanization alters recharge mechanisms and the water balance of an area. Several studies e.g. Lerner (1986), Thomson and Foster (1986) have shown that urban recharge is usually significant in arid and semi-arid areas and worth quantifying. The significance of this component is particularly important in Sana'a because water is being imported from outside the urban area, and because of the partial cover of the sewerage system which transfers water from the city to the stabilization ponds in alRawdha. The groundwater balance of the urban area in the Sana'a basin involves transport of water both into and out of the area.

Various methods can be used for estimating urban recharge. However, the most useful is the water balance technique,(Lerner et el,1990), which has been used in the present study.

The major components of urban water balance are:
- Import of water from the wellfield
- losses from the main distribution system
- Abstraction of water from private wells within the urban area
- consumptive use and the returns (domestic, irrigation, and industrial purposes)
- export of water out of the area by sewerage system, or tanks
- Return of water through cess-pits
- Recharge from Wadi alSyla

Analysis and discussion of each component is given in subsequent sections.

7.2 Urban Well Inventory

A systematic well inventory was carried out in Sana'a city during the period May to August 1993. The purpose of the well inventory was to update and obtain more information about the hydrogeological conditions of the urban area, more specifically, the groundwater abstraction, which represents a major component of the water balance. Without recent data for abstraction, reliable figures cannot be put on the unmeasured components of the water balance in the urban area.

In total, 161 wells were inventoried during this period. Probably not all wells in the urban area were visited, because some houses with wells were not accessible. However, it is believed that these are quite few, because the information for locating wells in any specific area was obtained from more than one source and from a responsible person (e.g. Imam of mosque). The area covered was about 40 km^2, which represents the city, excluding the part to the south of the southern ring road which was inventoried recently by the SAWAS project. Information about that part has been adopted from Bloemendaal (1990).

The inventoried wells were classified into 85 drilled wells and 76 dug wells. Among the drilled wells, 8 were out of use, either polluted (3 boreholes belonging to NWSA) or without pumps. All these boreholes belong to public places. 7 dug wells were out of use owing to collapse or back filling as the area is no longer under agricultural activity.

7.2.1 Field procedure & data collection

The well inventory forms used in the field with a summary of the data collected, are given in Appendix E. Some information was obtained by measurements (e.g. well yield, water depth, conductivity.etc). Additional information was supplied by the owners or users of the well.

Locations for the inventoried wells have been determined by means of Sony IPS-360, Global Positioning System (GPS). The accuracy of this instrument is ± 30 m (Elderhorst, 1993) and it does not work properly near high buildings, because it can not communicate with satellites. Hence some wells were located from a magnified copy of the topographic map (1:50000) using land marks, street names, mosques etc. Estimation of the elevation of wells from a topographic map within a plain area can result in error of ± 5 m (Bloemendaal, 1990). This is higher than the expected variation of the groundwater level within the city. So measurements were carried out for only certain dug-wells.

Water levels were measured using an electrical tape for relatively few wells. This is because all boreholes are equipped with submersible pumps and it was not possible to lower the tape into these boreholes as it can become stuck inside the borehole.

The yield of the wells was measured with a bucket and a stop watch. Measurements were carried out for 23 wells because most of the wells in the urban area discharge into closed tanks, some wells were not running during the visit and the owners were reluctant to run the pumps.

Electrical conductivity was measured at 45 wells by means of a portable EC-meter.

The owner of the well was asked about the age of the well, depth, depth of pump, duration of working, use of water etc. If the well was used for irrigation, the cultivated area was noted; if for sale of water, the number of tanks was also noted, questioning the drivers how many times a day they delivered water; and the number of houses supplied by the water was noted if used for water supply.

7.2.2 Well inventory Results

The coordinates as determined by the GPS-system have been converted to UTM coordinates by means of a special computer program (COORD) provided by SAWS II project. Location of the registered wells are given in Appendix E.

The importance of the age of the wells is to help define the historic development of abstraction from the area. However, peoples' memories are generally not accurate, especially for very old wells (dug-wells). The age of a drilled borehole is generally remembered more accurately. Table 7.1 shows the numbers of wells ranked with respected to their age. The rate of borehole drilling seems to be constant.

Table 7.1 Age of wells and boreholes

pre 1970	1970-75	1975-80	1980-85	1985-90	1990-93
82	17	19	17	18	8

The depth of the dug-wells is generally less than 60 m, and only a few metres below the water table. Three dug wells in Al-Hasaba area have depths of 6 m and they draw their water from local perched water, originating from local sewage disposal and infiltrating rain water and created by a local semi-permeable layer in that area. Table 7.2 ranks the depth of wells in more detail. However, there are only two aquifers present in the area: the loose Quaternary deposits with a thickness of less than 100 m and the underlying Tertiary volcanics. All the dug wells tap the Quaternary deposits, whereas the boreholes tap the Tertiary volcanics.

Table 7.2 Depth of wells and boreholes

Depth(m)	0-50	50-100	100-150	150-200	200-300	>300
no of wells	9	69	14	38	25	6

The conductivity of water samples from the wells range from 420 to 3040 µS/cm, as shown in Figure 8.7 (chapter 8). The bulk of the measurements are in the range of 1000 to 2000 µS/cm. Conductivities higher than 2000 µS/cm were found in wells located at old, densely populated areas, and in the shallow wells at Al-Hasaba. Most of the dug wells located near the main axis of the plain have high conductivity indicating poor groundwater quality in this area. The quality of water in boreholes in the centre of the city, or in populated areas depends upon the construction of the borehole, that is the depth of casing, e.g. a borehole in the centre of the city, cased up to 120 m below ground surface, has an electrical conductivity of 530 µS/cm (see chapter 8).

The amount of pumping varies between 7200 hours/year and 700 hours/year depending upon the use and depth, with a weighted average of 2570 hours/year (7 hours/day, 365 days).

The discharge rate per well varies between 2 and 9 l/s, with weighted average discharge rate of 5.3 l/s.

This average rate is lower than the value of 6.5 l/s, suggested by SAWAS (Blomendaal, 1990) for the south of the plain, and the computed average of JICA (1992) for the south eastern part (6.2 l/s). The difference can be explained by the fact that the yield was measured only for pumped boreholes in the both areas, whereas in Sana'a city half of the wells are dug wells with relatively low yields.

On the basis of the measured average yield, and duration of operation per well, abstraction per well has been estimated as follows.

If the average yield of 5.3 l/s is used with the average stated duration of working (2570 hours per year) for 145 wells, the annual abstraction per well would be 49000 m^3/year. If only the 23 wells with measured yield and duration were used in the estimation, the average annual abstraction would be 58500 m^3/year/well.

The number of the inventoried wells in operation is 145 wells out of the 161 registered wells. 17 wells have been adopted from recent work by Al-Derwish (1992) and Noori (1992). 59 wells in the south of the urban area were adopted from Bloemendaal et al (1990). Assuming 10% of the registered wells in the present study have been missed, the total number of wells in the urban area becomes 243 wells. A recent well inventory completed in 1995 by SAWAS (Pers. Comm. 1995) reported 250 operating wells in the urban area.

For the year 1993, the amount of groundwater extracted in the urban area is between 12.25 MCM (49000*250) and 14.6 MCM (250*58500), with average of 13.4 MCM. This figure seems consistent with previous estimates, see Figure 7.1.

7.3 Urban water use pattern and abstraction

In 1984, the population of Sana'a served by NWSA was 292,000, 68% of the total population (Grover, 1986). In 1990, the service coverage was 62% (392,000, using 8 people per connection *49000 connections) of the total population. Using 7 people per connection the percent of people supplied within Sana'a city would be 54%, which is more likely (Suleiman, 1991). According to data from the census 1986 (CPO, 1990), the average household size is 6.29 persons. TSHWC (1992) reported that 33 % of the urban population in 1990 of 870,000 i.e 287,100 people were served through the public water supply network and according to NWSA plans, this proportion will stay constant up to 1995.

NWSA's production during the first six months of 1993 (Personal comm, 1993) shows the gross water production for Sana'a as 8,761,950 m^3. Assuming that the same amount of water is pumped during the second half of 1993, the total municipal water use for the year will be approximately 17.5 MCM, including losses.

Assuming similar increase in the number of connections between 1985 and 1990, the number of connections in 1993 was estimated as 56,500, which means 339,000 people (6 persons per connection) are served by public water supply. This converts to a consumption rate of around 142 l/c/d. Taking 30% as losses, the per capita consumption becomes 99 l. The proportion of losses is based on figures for 1990 when the production was 12.6 MCM and water supplied 8.5 MCM, with losses accounting for 32%, NWSA (1990).

Using similar proportion as TSHWC (1992) during 1990, (i.e population served is 33% of 900,000) the per capita use would be 162 l/c/d and 113 l/c/d if the losses accounted for 30%.

The rest of the population (62% or 561000) is served by the private vendors. The water consumption per capita of people served by the private sector is believed to be less than those served by the public water supply network. The consumption suggested by Turkawi and Chaudry (1991) was 64 l/c/d for both. The Russians (Mosgiprovodkhoz, 1986) used 100 l/c/d for both, including water consumption in administrative, commercial and public buildings, and a constant 50 l/c/d for pavement washing and plant watering.

Suleiman (1991) reviewed the report of NWSA for 1990, and criticized the value of urban consumption of 59 l/c/d (based on a supply of 8.5 MCM/49000 connections * 8 people per connection), and which he considered to be too low compared with other urban centres in the world. He recommended a value of 100-120 l/c/d inclusive of losses. As reported by Al-Eryani et al (1992), Bloemendaal (1991) suggests 120 l/c/d for the population on mains supply, considering that 20-25% accounts for losses from the system and illegal connections, and 80 l/c/d for the other supply sources. The lower rate is explained by the higher cost of water purchased from private suppliers, less convenience and possibly lower income levels of the population so served. This is true for the population who buy their water from cars.

However, another part of population not served by the public network (8%) is provided by water through connections from private water companies. Moreover, it is understood that they pay less than those connected to NWSA. Analysis of abstraction from some of these wells, with the number of houses (6 person per house) supplied with water, suggests an average value of 80 l/c/d including losses, (e.g. borehole nos 5,24,68). From the inventory data, 44,000 people receive water through these private services. Consumption of 80 l/c/d appears too high for the population who buy their water from vendor's cars, 35 l/c/d reported by TSHWC (1992) and present observations seems reasonable. The total consumption from private water supplies was estimated in 1993 as 7.8 MCM (44,000 * 80 * 365 = 1.2 MCM & 517,000 * 35 * 365 = 6.6 MCM).

On the basis of well inventory information, the remaining 5.5 MCM was divided into irrigation consumption (2.0691 MCM) and industries (3.648 MCM). More discussions are given in subsequent sections (7.4.3.2-3).

The abstraction from the Sana'a city (over an area of 40 km^2) estimated by the Russians in 1984/1985 (Mosgiprovodkhoz, 1986) as 9.1 MCM including domestic supply (1.825 MCM), industries (1.825 MCM), and pavement washing and plant watering (5.475 MCM). Although the figure for abstraction is reasonable comparing to the estimates in 1972 and 1993, the distribution between different sectors was inconsistent. This is because they used 50 l/c/d for pavement washing and plant watering (5.475 MCM), however, there is no pavement washing in the Sana'a city and the areal extent of the green areas within the city is relatively small compared with the overall urban area.

The 1.825 MCM for domestic, public and commercial is not reasonable because, if NWSA's service covers 292000 in 1984/85 out of the 427502 people (February, 1986), the total population, the rest must have their water from private sources. Using same value of 100 l/c/d as the Russians in 1984/85 for domestic water use including water consumption in administrative, commercial and public building, the abstraction would be about 4.9 MCM. Moreover, they estimated the return through cess-pits as 8.3 MCM, which means if the above figure was used (1.825 + 9.125), the return would be higher than the supplied water after deducting the losses (30%) in the mains. (see urban domestic consumption, section 7.4.1).

Al-Eryani et al (1992) suggested between 2 and 5 % of the total urban area (100 km^2 based on 90 km^2 in 1984/85) is planted, and accordingly the annual abstraction for irrigation would range from 2 to 3 MCM. This figure can not be compared with the private abstraction given by Mosgiprovodkhoz (1986), because the urban area is different. Using the same percentage over 40 km^2, the irrigation abstraction in 1984 would be 1.254 MCM. Presently, from the well inventory information, the irrigated area within the city was estimated as 330 ha and the abstraction as 2.0691 MCM. It is believed that the irrigated area within the city remained more or less constant over the period between 1984 and 1993 and it will stay the same, at least for the farms. This is mainly because most of these farms are "Wagaf" inherited to be cultivated. From the above, 1.825 MCM, which is used as a basic unit for distribution of the abstraction over Sana'a city by the Russian team, was considered to be abstraction for irrigation in 1984 in Sana'a city. The rest was allocated with the domestic, commercial and public urban use. A summary of water use pattern in 1972, 1984 and 1993 are given in Table 7.3. The data for private abstraction were used to extrapolate the abstraction between 1972-1993 as illustrated in Figure 7.1.

Table 7.3 Various Urban abstraction estimates

Water sectors	Ital.1973, m^3	Mos. 1984* m^3	1993 m^3
Public supply	1,022,000	9,791,720	17,523,900
Private supply	1,402,000	5,475,000	7,682,900
Industries	661,000	1,825,000	3,648,000
Irrigation	1,273,200	1,825,000	2,069,100

* modified from Mosgiprovodkhoz estimate, (Grover, 1986)

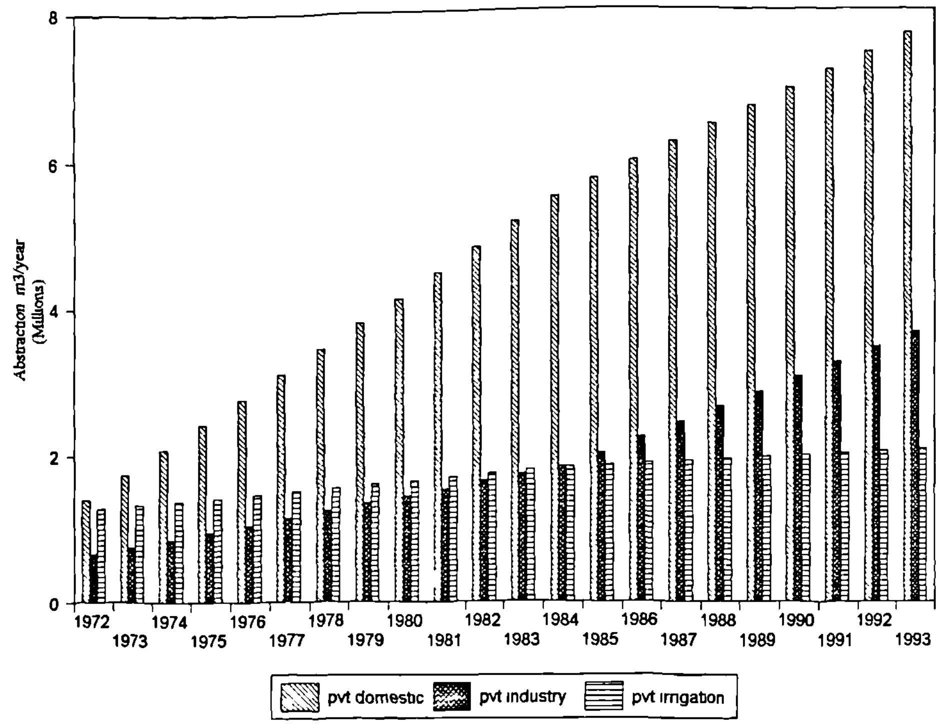


Figure 7.1 Distribution of private abstraction.

7.4 Urban Water balance components

7.4.1 Supply water and Mains leakage

Table 7.4 shows the annual abstraction from the wellfield supplying Sana'a water demand. During the last 20 years the abstraction in the wellfield area increased from 1.02 MCM in 1972 to 18.7 MCM in 1992. A steep increase in abstraction in the western wellfield, however, starts in 1980, when the production wells drilled for the Sana'a water supply phase 1 became operational. In 1984, another increase occurred when the eastern well field came on-line. The increase in 1988 came as a result of the emergency well drilling programme, and the increase in 1992, because new boreholes replacing existing wells came in operation.

Table 7.4 Annual abstraction (m^3) in Sana'a water supply

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source; Mosgiprovodkhoz, 1986 (1972-1984),
Laes and Bamatraf, 1991 (1985-1990),
NWSA Sana'a Branch, (1991-1993)

As can be seen from the table, the production is not monotonic with time. Production of year 1985 is less than 1984 and 1986 is less than 1985. For year 1993, with detailed information, it was found that some boreholes did not work for few months, probably due to pumps problems. However, a general trend of increase is clear.

Leakage from water mains cannot be measured directly. There are two common practices for estimating leakage. The easier one is to take a proportion of the water supplied. Typical values of this proportion are 25 to 35% but values of 10 to 60% have been reported (Lerner et al, 1990). However, this practice has higher potential errors and its accuracy depends on the selection of the accurate proportion, which is either guessed, transposed from another city, or estimated for a small area using difference between supply and use. The latter is more accurate and is a common technique used in the water supply industry to estimate leakage, ('minimum night flow' measurements). This has been adopted for the present study, however a review of previous suggestions are discussed first.

Grover,(1986) based on NWSA report for water supply data for Sana'a between 1981-1985, used 25% losses (of abstraction) from the mains. NWSA report indicates that in 1990 the water supplied was 8.5 MCM, but abstraction details of boreholes show 12.6 MCM. This implies that the losses account for 32% of the water abstracted. Suleiman (1991) estimates that losses in the system are in the order of 20%. Lloyd (1992) reported losses from the water supply system as 25% of the supply and that the return flow to the aquifer from this source is 50% of the losses (i.e 12% of the supply), however the basis for using only 50% of the losses is not mentioned. Al-Eryani et al (1992) believed that the return flows from losses in the system are negligible because illegal connections are common, there is a great thickness of unsaturated zone (40 m) and the losses are scattered over a large area. Several studies in similar arid and semi-arid areas have shown that leakage from mains can be a significant source of recharge, for example in a Doha (Qatar) and Lima (Peru) (Lerner et al. 1990) the return leakage of mains alone was estimated to be 22% and 28% of the total recharge to the aquifer (or 30% of the supplied water). The unmetered use is frequently estimated from population and per capita consumption, and consumption of 64 l/c/d supports losses of 20% of the abstraction (for the private abstraction area). In estimation of leakage, there is a factor to allow for the commonly occurring under-recording of meters which ranges from 1-10% (Dangerfield, 1983), and this to a degree, would cancel the unmetered use reported by Al-Eryani et al.

The assumption that only part of the gross leakage becomes recharge is possible, because some leaks may occur within consumers' premises, or may flow to the sewers. In Lima, the first estimate of recharge from leakage was 40% of the average supply, but this has been revised downwards in the modelling studies to 30% (Lerner, 1986). From this discussion and based on NWSA's figures, losses from NWSAs' mains are taken as 30%, and from private distribution pipes as 20%. The return to the groundwater is assumed to be 50% of the losses, taking into account the illegal connections. Recharge was calculated by interpolating the private domestic abstraction between 1972 and 1993, and using information on public domestic supply given in Table 7.4. Figure 7.2 illustrates the annual recharge through leakage from private and public mains between 1972 and 1993 and annual figures are given in Table 7.6.

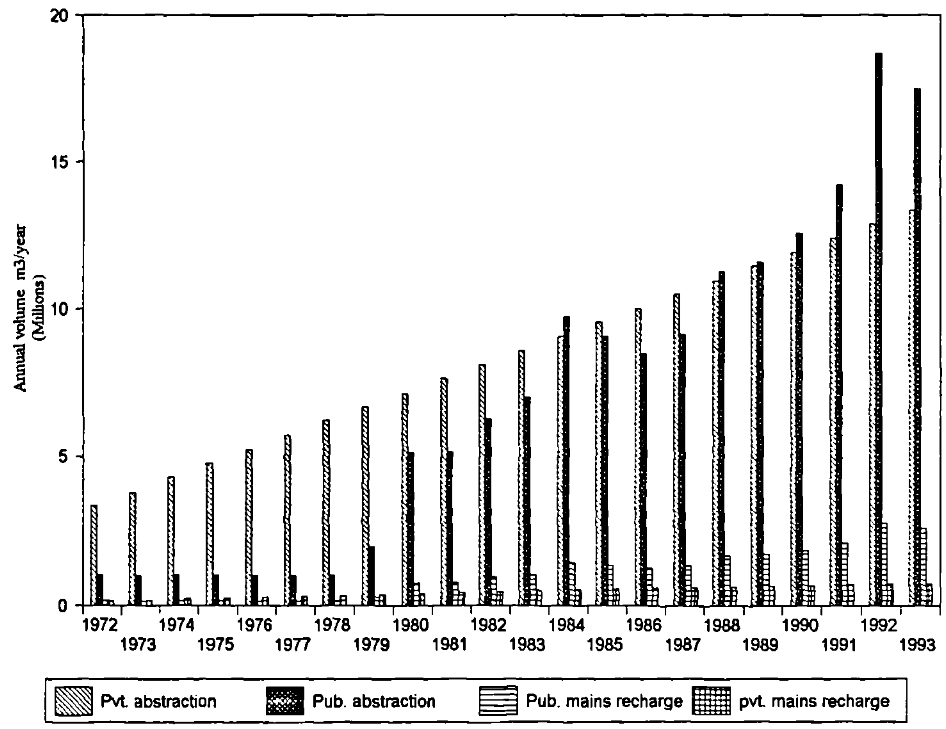


Figure 7.2 Total annual public and private abstraction and leakage from mains (1972-1993).

7.4.2 Water transferred out of urban area

Waste water is collected by the sewer network and discharged into the stabilization ponds at alRawdha. The sewerage network covers 12% of the population of Sana'a, (104,000) estimated by Suleiman (1990). He estimated the quantity of waste water at 8300 m^3/day (3 MCM/year). Lloyd (1992) used 10000 m^3/day. More recently Al-Eryani et al (1992) reported average measured daily discharge into the ponds of about 7000 m^3/day. Leakage from sewers is difficult to estimate because it requires details of sewer construction, their leakiness and the properties of the adjacent soils, and has not been reported in the literature. In comparison with the groundwater leaks into sewers, it is reasonable to assume that high leakage rates are possible for sewers above water level (Lerner et al, 1990). However, Lerner (1986) believes that leakage will be low because sewers are generally un-pressurized. In the present study, it was assumed to be negligible.

Another type of transfer of waste water outside the urban area is through tankers, which has not been estimated before. No records are available, but from questioning drivers, 200,000 m^3/year of waste water is being transferred through tankers.((10 cars, 3 times a day, i.e 30*20=600 m^3/day). Before the sewerage system was commenced in 1986, this was the only method to transfer waste water outside the urban area. The value of 200,000 m^3/year was used between 1972 and 1985, whereas a value of 7500 m^3/day including the water exported by tankers has been adopted between 1986 and 1993. The annual variation of water supplied for Sana'a city between 1972 and 1993 is shown in Figure 7.3. These figures have been used to estimate the part of the supply water that discharged into cess-pits. Examples for 1972, 1984 and 1993 are given in Table 7.5

Table 7.5 Volumes of water supplied, transferred out of urban area and net supply, (m^3).

Categories	1972	1984	1993
Supplied water	1,837,000	11,234,204	18,413,050
Transferred out of area	200,000	200,000	2,737,500
Net supplied	1,637,000	11,034,204	15,675,550

7.4.3 Consumptive use and return

7.4.3.1 Domestic use and cess-pits return

About 88% of the population of Sana'a city are served by cess-pits. Waste water discharge into cess-pits in areas of the city which are not connected to the sewer network can be assumed to recharge all the water they receive (Lerner et al, 1990), as the flows are discharged to greater depth (10-15 m). Lloyd (1992) used 75% of flow to the cess-pits as a return to the aquifer, which is equal 35% of the all water supplied by NWSA, however, the basis of the calculation, is unknown. Al-Eryani et al (1992) reported significant return flow is taking place through cess-pits and suggested 80% of the supplied water might be considered as return to the aquifer.

In 1984, prior to installation of the treatment plant, Mosgiprovodkhoz (1986) estimated return through cess-pits to be 8.2855 MCM/year, which was equal to 90% of water abstracted by NWSA (9.125 MCM/year), 76 % of the total abstracted public and private water for domestic use (10.95 MCM/year), or to 51% of the total abstraction for urban area (16.352 MCM). However, using the corrected abstraction (section 7.3) for 1984, the return was estimated as 57% of the abstracted water for domestic use (14.6 MCM) and 77% of supplied water for domestic use (10.77 MCM). Consequently the consumptive use was estimated as 16 l/c/d. Based on daily consumption of water in several cities, Dangerfield (1983) suggested 20 l/c/d for consumptive use. On basis of the above, and from local information, 80% of the supplied water appears an acceptable figure for the water return to the aquifer through cess-pits. The recharge through cess-pits between 1972 and 1993 has been calculated as 80% of the net supplied water (i.e after deducting the part that is transferred out of the area by the sewerage or tankers). Annual return flow through cess-pits is given in Table 7.6 and illustrated in Figure 7.3, with the volumes of supplied and transferred water.

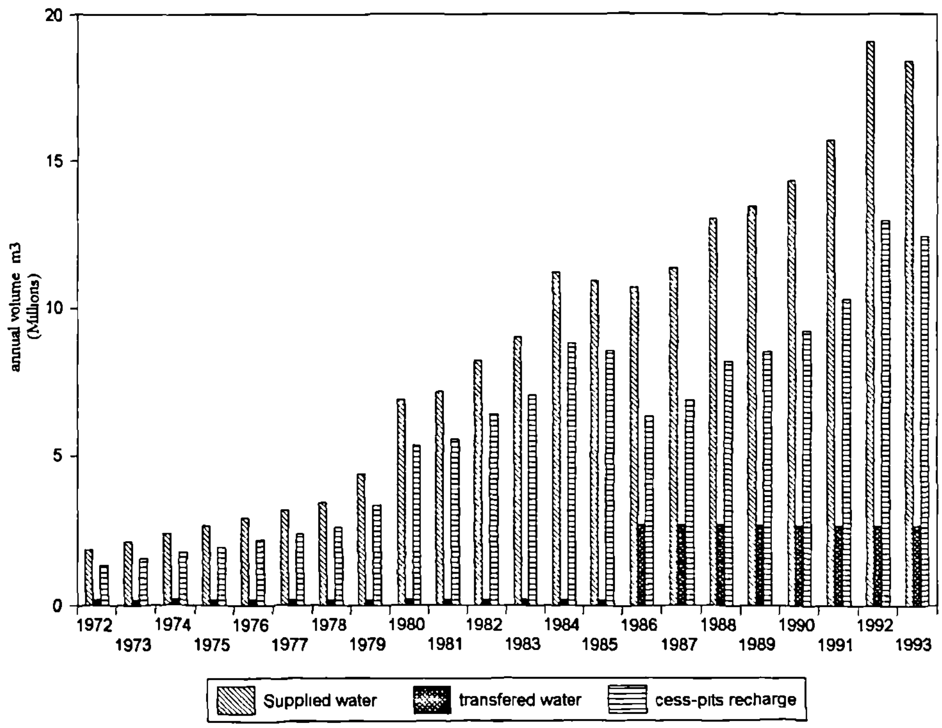


Figure 7.3 Supplied, transferred and cess-pits return

7.4.3.2 Industrial use and return

No comprehensive survey has been carried out of industrial abstraction. Most industries have private boreholes and dispose of the waste water locally. They do not keep records of abstraction or waste disposal. Thus there are no measured data on the use of water by industry in the region. Based on government master plan, Italconsult (1973) estimated industrial abstraction as 0.7 MCM/yr. By the year 1984, Mosgiprovodkhoz (1986) estimated the industrial abstraction as 1.825 MCM/yr. Chaudry and Turkawi (1991) estimated industrial water demand as 4.6 MCM for Sana'a governorate during 1989, based on the industrial survey of 1986 and adjusted UN water use coefficients.

The industrial water demand projections mainly involve manufacturing, and are based on the assumption that this sub-sector will grow at an annual rate of 6%, as compared to the historical growth rate of about 12.3% and the planned growth rate of 8% (TSHWC, 1992). Assuming water demand per unit to be constant, the industrial water demand in the basin area would be 5.7 MCM for 1993. The growth rate of 8% within the city seems realistic and has been used, however the base year used for estimation is that of 1984 (Mosgiprovodkhoz, 1986). The present day (1993) industrial water abstraction within the urban area is 3.648 MCM/yr. This figure used with those of 1972 and 1984 to interpolate the industrial abstraction between 1972 and 1993. The industrial water return requires data on the type of the industry, so that the consumptive use can be estimated and the method of the discharge of their waste water. Both items require a lot of data which is not available. As the amount of industrial water use is not significant, 25% has been adopted in the present study. The return from industrial water supply between 1972 and 1993 is given in Table 7.6 and illustrated in figure 7.4.

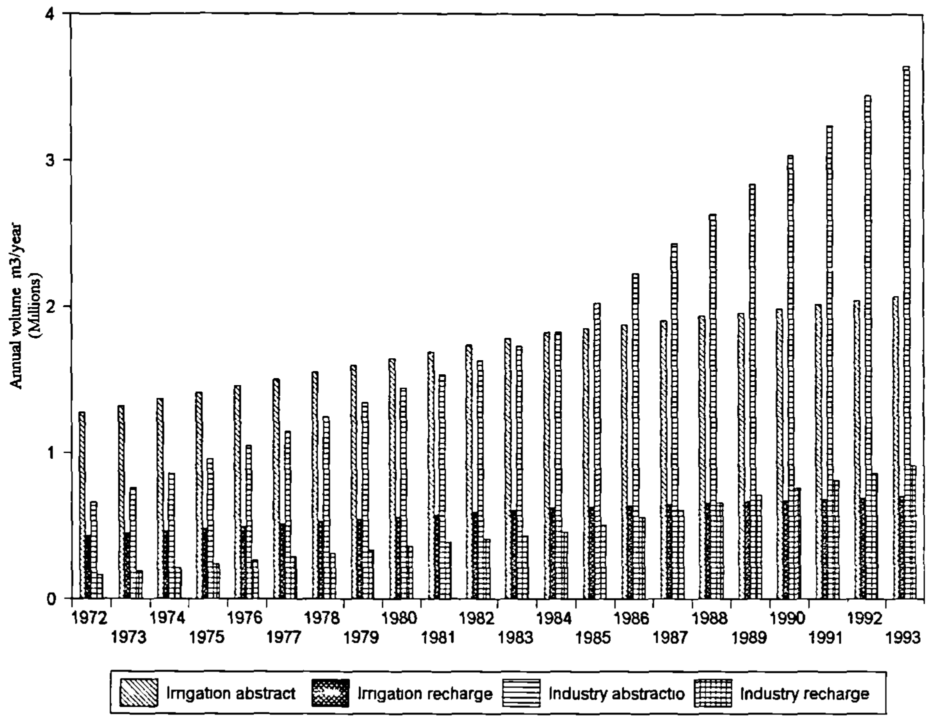


Figure 7.4 Industrial and irrigation abstraction and return flow.

7.4.3.3 Irrigation use and Return

The reported abstraction for irrigation and pavement washing within the city in 1984 by the Russians was 5.4 MCM/year (Grover, 1986). In section 7.3, it was shown that this figure is not reliable, and 1.825 MCM was suggested to be the abstraction for irrigation during 1984. The areal extent of the irrigated area within the Sana'a city could not be traced in any of the available reports. However, an attempt to estimate this area as a percentage of the whole urban area was made by Al-Eryani et al (1992), who suggested a value between 2 and 5 %. Based on data on the number of wells and boreholes used for irrigation from the well inventory during 1993, the remarks about the irrigated area during the field visits and the average command area recommended by Hussein and Noman (1991), abstraction for irrigation was estimated as 2.0691 MCM/year for an irrigated area of about 330 ha. This area uses 110 wells and boreholes for irrigation.

The irrigation return was estimated from the amount of abstraction for irrigation using an average percentage of 34%, (chapter 4). Although this recharge component has already been included in the regionalization of the irrigation return over the Sana'a basin, it has been calculated here only for the subsequent analysis of ground water level fluctuations, recharge and abstraction (chapter 9) within urban area. The annual irrigation abstraction and return is shown in Figure 7.4.

7.4.4 Recharge from Wadi alSyla

The part of the Wadi alSyla that runs through the city has a catchment of 130 km^2. The flows along the wadi were estimated from the rainfall-runoff model. By substituting the wadi flow into the regression equation developed in chapter 5, recharge through wadi alSyla during period 1974-1993 was computed (Figure 7.5) giving an annual average of 1,144,691 m^3. The detailed results are given in Appendix E. The recharge from Wadi AlSyla was estimated for subsequent use in analysis of the ground water level fluctuation within the urban area, although it has already been included in total figures for wadi recharge given in chapter 6.

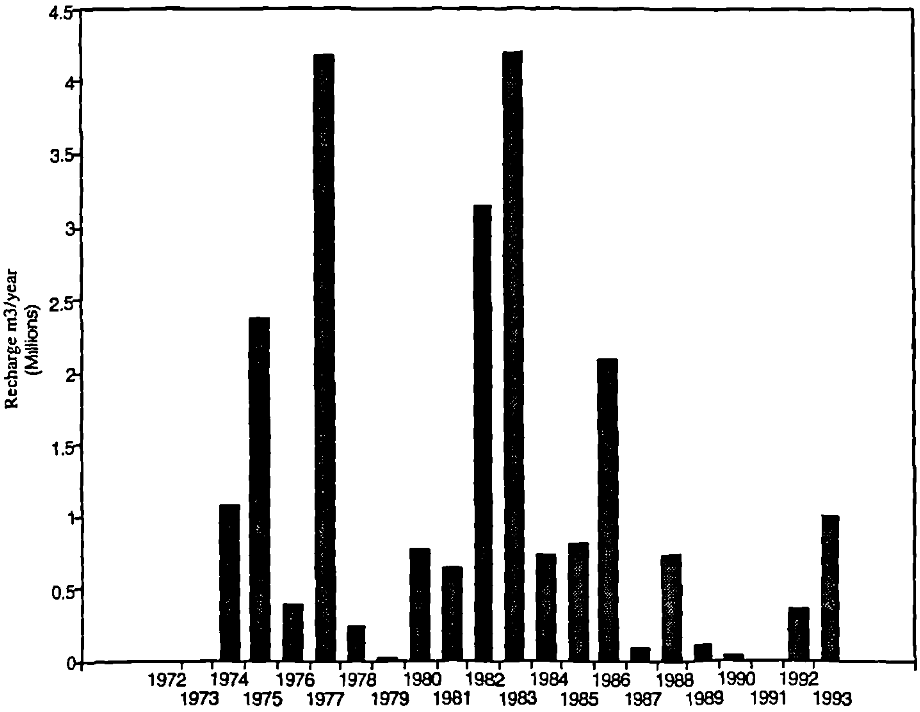


Figure 7.5 Wadi Al Syla recharge

7.5 Urban recharge component results

The various components of urban recharge are shown in Table 7.6 for the period between 1972 and 1993 and illustrated in Figure 7.6. The highest recharge component is the return flow through cess-pits, which increases linearly from 1.3 MCM in 1972 to 6.5 MCM in 1985. A reduction of about 2.7 MCM/year was a result of sewerage system, which started in 1986. However as there was no expansion of the sewerage system, and due to the continuous increases of water supply, the recharge through cess-pits reached about 12 MCM during 1993.

Table 7.6 Various urban recharge components

compo nent-year	Pub. mains MCM	Pvt. mains MCM	Cess-pits MCM	Industry MCM	Irriga-tion MCM	Wadi MCM
1972	0.153	0.140	1.310	0.165	0.433	-
1973	0.153	0.174	1.527	0.189	0.449	-
1974	0.153	0.208	1.744	0.214	0.464	1.078
1975	0.153	0.242	1.961	0.238	0.480	2.358
1976	0.153	0.276	2.179	0.262	0.495	0.381
1977	0.153	0.310	2.396	0.286	0.511	4.183
1978	0.153	0.344	2.613	0.311	0.527	0.240
1979	0.295	0.378	3.362	0.335	0.542	0
1980	0.779	0.412	5.386	0.359	0.558	0.753
1981	0.777	0.446	5.595	0.384	0.574	0.640
1982	0.947	0.480	6.446	0.408	0.589	3.151
1983	1.057	0.514	7.072	0.432	0.605	4.200
1984	1.469	0.548	8.827	0.456	0.621	0.727
1985	1.367	0.572	8.605	0.507	0.630	0.806
1986	1.283	0.597	6.417	0.558	0.639	2.077
1987	1.381	0.621	6.941	0.608	0.648	0.100
1988	1.701	0.646	8.292	0.659	0.657	0.737
1989	1.747	0.670	8.620	0.709	0.667	0.105
1990	1.891	0.695	9.317	0.760	0.676	0.035
1991	2.139	0.719	10.397	0.811	0.685	0
1992	2.809	0.744	13.058	0.861	0.694	0.342
1993	2.639	0.768	12.540	0.912	0.703	0.983
average	1.061	0.477	6.118	0.474	0.584	1.145

The maximum indirect recharge was during 1977 and 1983, when it reached 4.2 MCM. The indirect recharge is erratic and does not occur every year; for example during 1991, there was no wadi recharge.

The leakage from the public and private mains varies between 0.3 MCM in 1972 to 3.5 MCM in 1993.

The annual irrigation return flow did not vary as much as other urban recharge components. It increases from 0.3 MCM in 1972 to 0.7 MCM in 1993. The slower rate of increase during 1984-1993 within the city, in contrast to the rest area of the basin, is the result of building expansion.

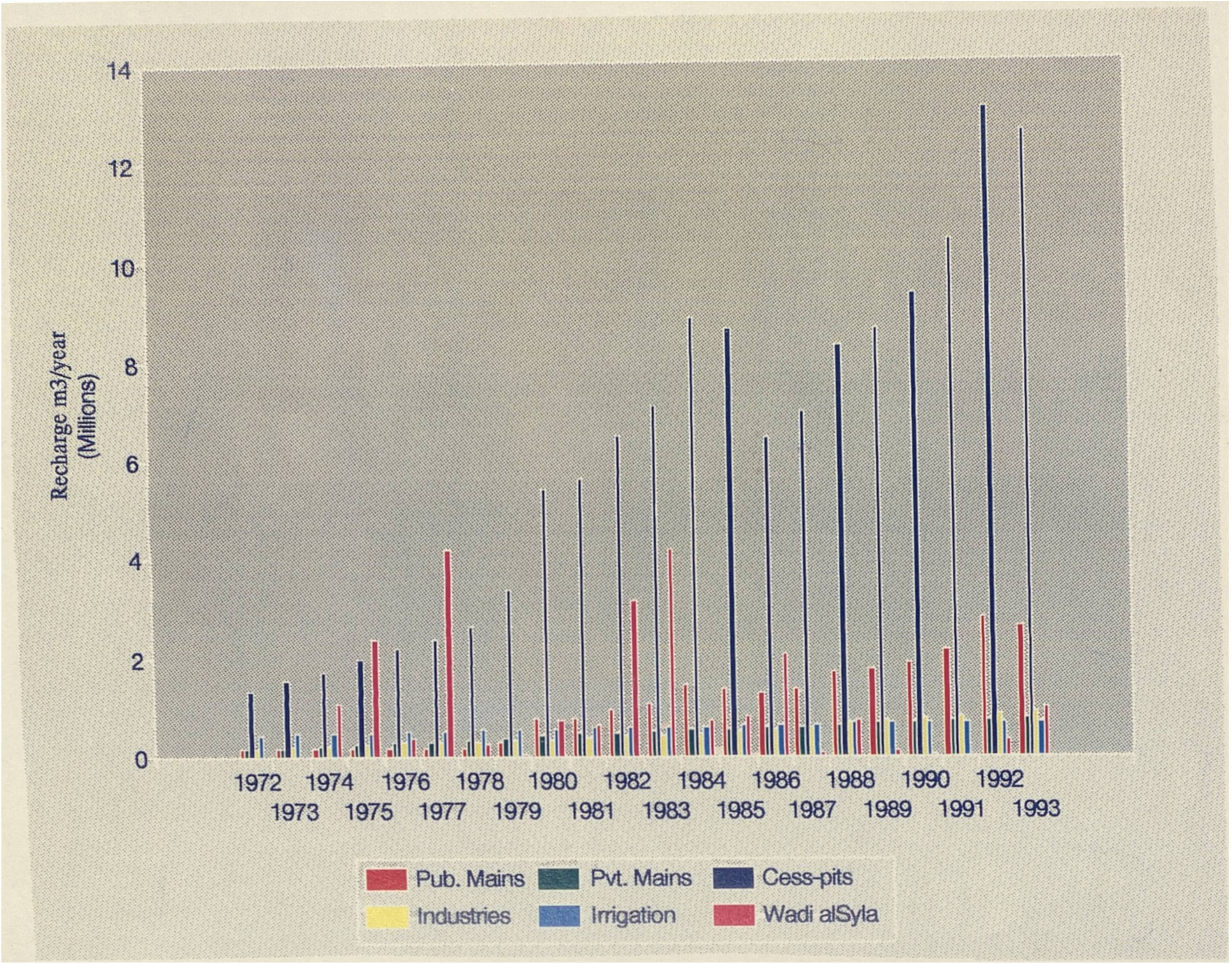


Figure 7.6 Various urban recharge components (1972-1993)

The industrial return increases from 0.2 MCM in 1972 to 1 MCM in 1993. The annual increase of this component has doubled during the period between 1984 and 1993 as a result of the government's encouragement of industry.

8 HYDROCHEMISTRY

8.1 Background

Mountainous areas present special problems in hydrologic analysis, and simple relations given by Hubbert (1940), and substantiated in numerous studies in low-lying sediments, may not apply to the Sana'a basin, which is also characterized by a fracture permeability. Foster and Smith (1988) conclude from studies in mountainous areas that permeability has the greatest impact on the mountainous flow system; asymmetry can cause the displacement of the groundwater divides from the topographic divides, and a relatively small increase in the vertical permeability of fractures relative to the horizontal permeability causes significant declines in the water table elevation. Hydrochemical techniques are particularly useful when multi-aquifer situations or strong transmissivity variations make the straight forward interpretation of piezometric data impossible (Lloyd & Heathcote,1985).

Alderwish, (1992) established the chemical composition for individual aquifers in the Sana'a basin and describes various geochemical processes that might contribute to the evolvement of the existing groundwater. In the present study the objective is to complement the analysis of recharge through examination of hydrochemical trends across the region and the impact of man-induced recharge components on the groundwater quality.

8.2 Field work and laboratory analysis

8.2.1 Sampling method

66 samples were collected from wells, including 1 spring and 1 rainfall water sample during September 1993, covering most of the Cretaceous sandstone aquifer and the Sana'a plain. The second sampling programme was carried out during March/May 1995 and 45 groundwater samples were collected, mainly from the central plain and areas defined from initial analysis of results from the first sampling programme, with special emphasis on the urban area.

Similar field procedure was used in both programmes. Sampling of springs was made as close as possible to the principal outlet, and only wells in use were sampled, after the water standing in the well had be pumped out so that inflow to the well could be sampled directly. The sampling of groundwater from pumped wells was accompanied by information on the well, particularly the location of screens and the aquifer(s) tapped.

Two samples from each water point were taken in pair of clean (new) polythene 100 ml capacity containers. In addition, 40 samples were collected in glass bottles '100 ml' for isotope analysis. At the site, the container were rinsed using the water being collected. Then the container were filled with water so that there was practically no air left in the containers. All samples were filtered at the sites and one of each pair for cation analysis was acidified using hydrochloric acid. The location of the sampling points are shown in Figure 8.1.

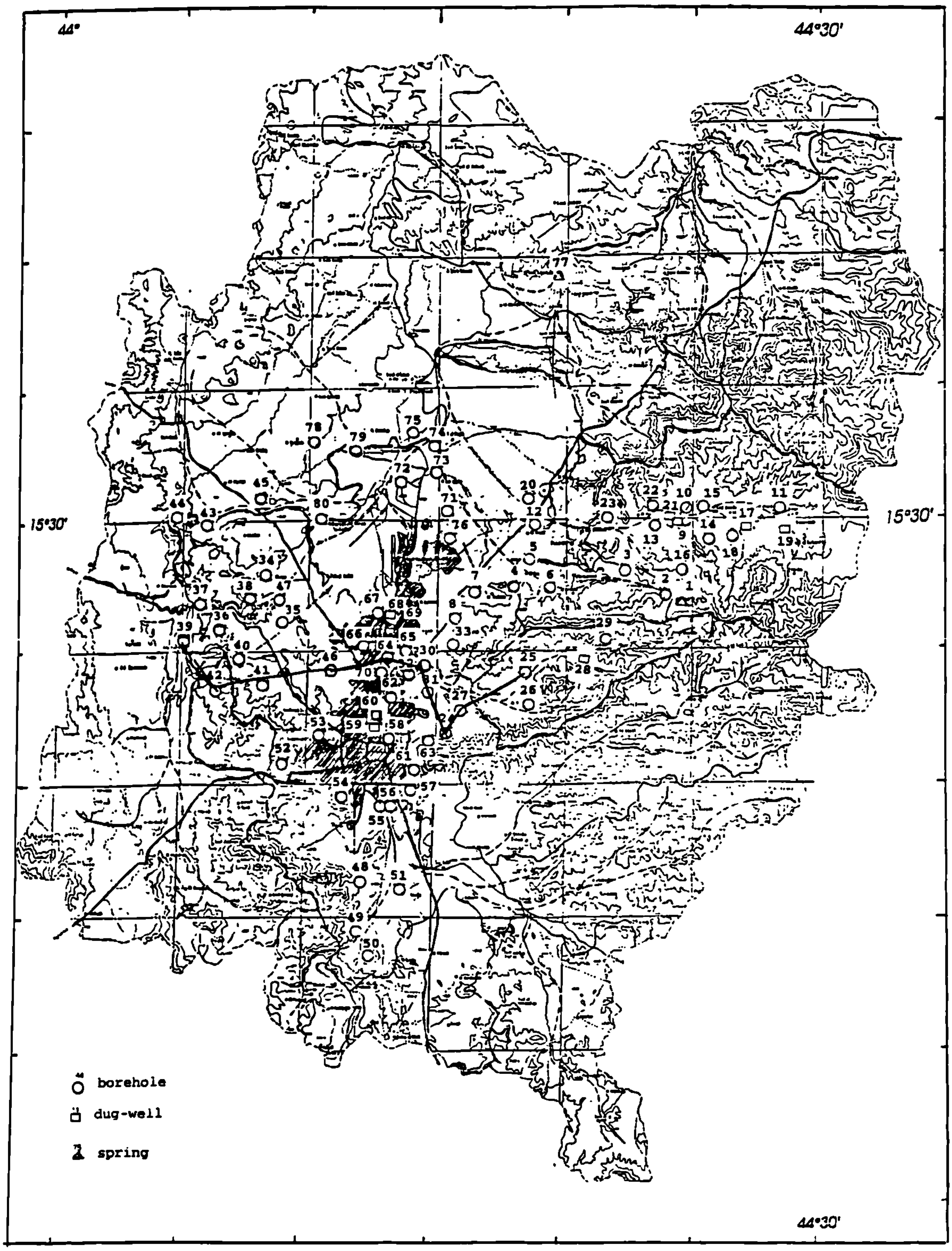


Figure 8.1 Water sample locations

3.2.2 Field parameters measurements

The purpose of making measurements at the well head is for convenient rapid assessment and to provide control for laboratory measurements. The latter is important in that the physical conditions of a sample may change between the time of sampling and the laboratory measurements. The field parameters measured at the field were, EC, T, pH, Eh, DO and Alkalinity.

The measured electrical conductivity, is a measure of conductivity (concentration) of a solution because the ability of solution to conduct the current is a function of the concentration and charge of the ions and the rate at which the ions can move under the influence of the potential. The simplicity of measurement of electrical conductivity makes it a practical standard, and it indicates the total dissolved solid of the water sample.

The measured pH is a very important parameter in geochemical equilibrium and speciation calculations. However, two problems were noticed. The first is that the degree of precision requires careful work and special attention to electrode maintenance, buffer solutions, and temperature corrections. The second problem arises from the effects of temperature and mixing of water from different aquifer sections in pumping wells, which may make interpretation of the most carefully determined pH values a very uncertain and difficult task.

Measurement of temperature is required for control of other measurements, as all other parameters are sensitive to the temperature. Also it may be used to differentiate between recharge and discharge areas.

Measurement of dissolved oxygen requires special sampling equipment. Although a through-flow cell was not available, where possible, the electrode was immersed into the pipe, so that measurement was taken before the water came into contact with air. The measured dissolved oxygen in groundwater has a special importance in recharge studies and can be used to indicate recharge water and even relative age (e.g. Edmunds et al 1982).

Measurements of Eh in natural waters represent mixed potentials, and many equilibria involving electron transfer can contribute to the Eh of a water, so that the redox potential of a natural water is not a clearly defined quantity like pH. In fact a range of redox values for different couples (e.g. Fe^{3+}/Fe^{2+}), $O^{2-}/(OH)^{-}$ etc, may coexist in any given water sample. Stumm and Morgan (1981) concluded that the use of a single Eh to characterize oxygenated water is meaningless because the various redox couples may not be in equilibrium with each other. However, it can be useful as general indicator for the redox condition. The observed range in the Sana'a basin was - 0.157 to 0.06 V*.

Alkalinity was measured by titration with H_2SO_4 and indicators, phenolphthalein for carbonate and methyl-orange for bicarbonate.

* *Water in contact with atmosphere (PH=7), has Eh range from +0.7 to +0.8 volts; water at outcrop containing dissolved oxygen, nitrate, and sulphate has an Eh of about +0.4 V; as it become reduced, Eh falls to +0.1 V, then falls to -.1, also can go as low as -0.4 V.*

8.2.3 Analytical method and results

The analytical analysis was performed using Ion Chromatography for the major anions CL^-, SO_4^{2-}, NO_3^-, F^-. This was carried out for all samples collected from first field work and only 15 samples (out of 45 samples) from the second field work, because the un-acidified samples were lost from UCL laboratory.

An ICP system (Inductively Coupled Plasma Spectrometry) was used to analyze all water samples from both field work for major cations. Analysis of samples from the first field work was carried by the author, and for the second field work by Tony, a UCL technician.

Trace elements (Fe and Al) were further analyzed for first field work samples using AAS (Atomic Absorption spectrophotometry) by Tony.

Samples collected for stable isotopes analysis were not analyzed. This is mainly because it is believed that the analysis procedure used and described by Matin (1994) is tedious and time consuming. Also it was understood that due to technical problems the laboratory of Royal Holloway and Bedford College will not be available until June 1996.

5 groundwater samples were analyzed by ACTIVATION laboratories ltd. (Canada) for tritium content using tritium-liquid scintillation counting technique. The results are given in Appendix E.

The chemical analyses given in Appendix E were processed using the WATEQ4F version (1992). Description of this program can be found in the manual (Ball and Nordstrom, 1991). Although this program calculates several parameters, (see Alderwish, 1992), few were useful in the present study. The results of the calculated ion balance error for samples are less than 5%. Samples with more than 5% were re-analysed.

8.3 Hydrochemical variation

The classification of water chemistry is intended to describe the hydrochemical variations in the Sana'a basin system. The basis of the classification used in this study includes both chemical composition and chemical change, together with elements of geological and geographical control. The latter elements are found essential to provide meaningful interpretation with respect to the present study.

Using a map to show the variation can help not only to observe a systematic areal distribution of water quality, but also allow correlations with other characteristics of the groundwater system. It is common practise to map the chemical variations first before classification of water type. However, it was found more useful here to distinguish water types using an expanded Durov diagram, before and in conjunction with preparation for distribution maps and hydrochemical sections. Chloride ion concentration was used in the distribution map because it is a comparatively conservative ion which increases down the hydraulic gradient and can reflect the hydrochemical evolution of groundwater. The normal chloride concentration increase is only disturbed where pollution or dilution occurs so it is an excellent indicator of groundwater flow direction and preferential permeability conditions.

In accordance to the objective of the study, the basin was divided into three parts; eastern, western and central parts, and the hydrochemical variation is described for each one. Also as many boreholes derived from more than one aquifer, the hydrochemical variation are described first by region, and then in summary are related to hydrochemical trends of specific aquifers.

8.3.1 Eastern plateaux

This area covers Wadis AlSir, Rujam, AlRawna and their mountain front, and has been covered by 35 samples taken from a spring, 5 dug-wells and 29 drilled wells. Three aquifer are present within this area; Cretaceous Sandstone, Volcanics and Quaternary loose deposits. Figure 8.2 illustrates an expanded Durov diagram and accordingly four water type can be identified;

1- Calcium-Bicarbonate water
2- Calcium-indiscriminate anion water
3- Sodium bicarbonate water
4- Calcium-chloride water

13 samples have **Calcium-Bicarbonate water type**, all drawn from the Cretaceous Sandstone aquifer. The spatial distribution of chloride concentration of these samples is drawn in Figure 8.3 in an attempt to investigate any relation with the hydrogeological conditions. The area of least chloride concentration coincides with the area of greatest fracture density, and generally represents a recharge area to the Cretaceous Sandstone aquifer. The chloride concentration decreases in the direction of groundwater movement according to hydrogeological map (Mosgiprovodkhoz, 1986). This can be explained by, the older water from the eastern part of the basin, where the Cretaceous sandstone lies under the Tertiary volcanics, being diluted by fresh recharge water from wadis and the mountain front along the aquifer outcrops.

High chloride concentration is also found in the plain (sample, 64) where the Cretaceous Sandstone is overlain by a considerable thickness of alluvial aquifer.

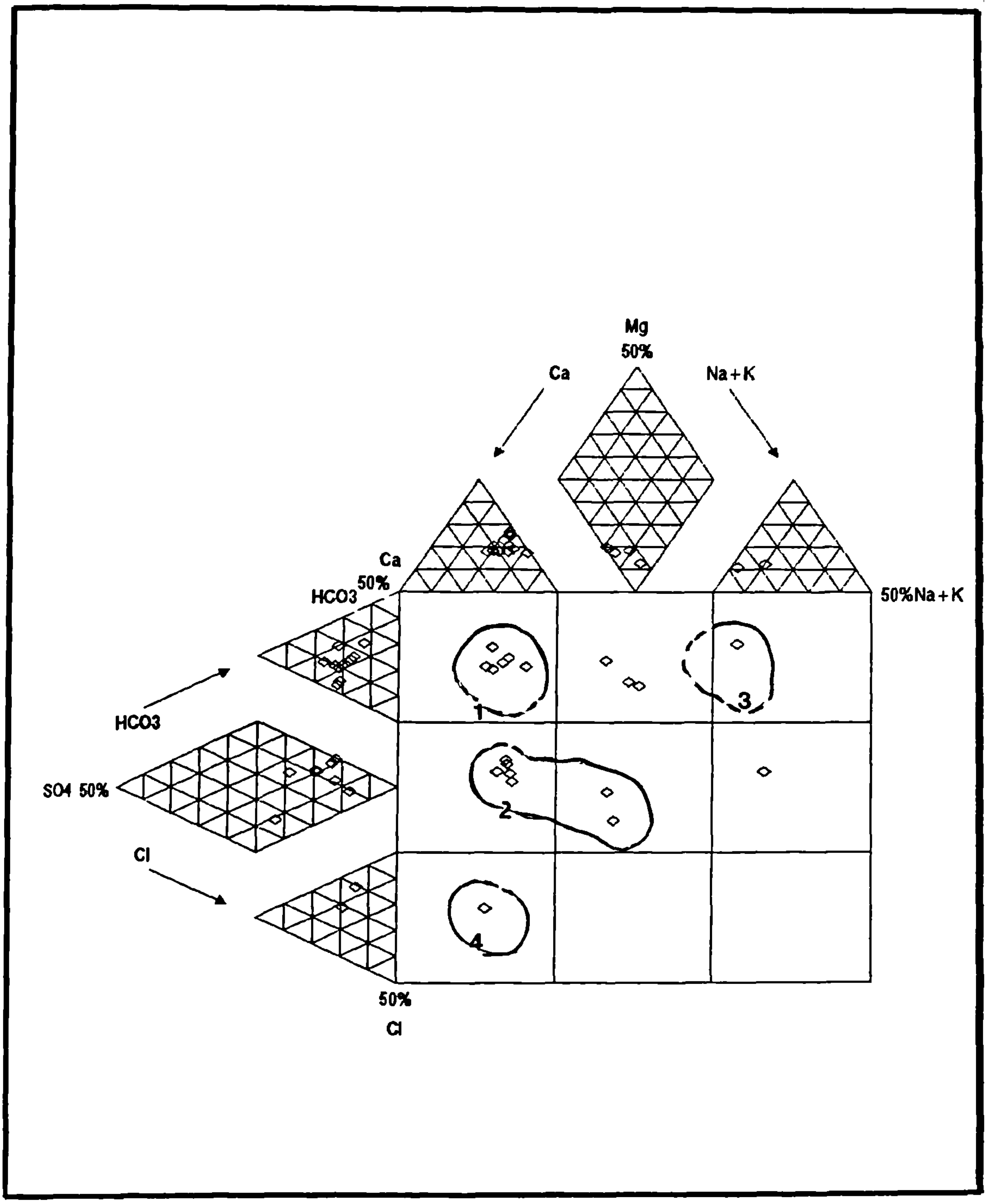


Figure 8.2 Expanded Durov diagram for groundwater of the eastern plateaux

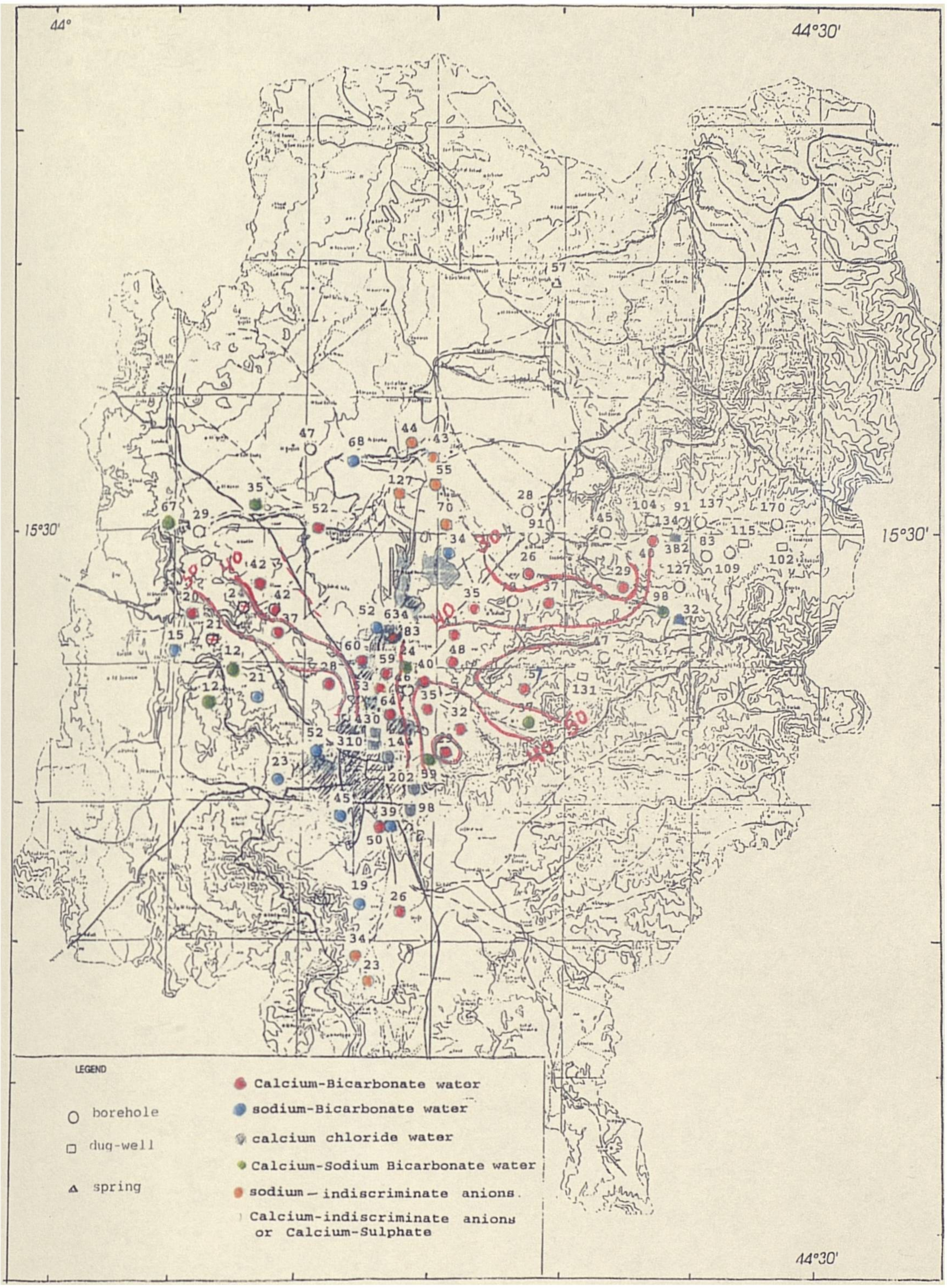
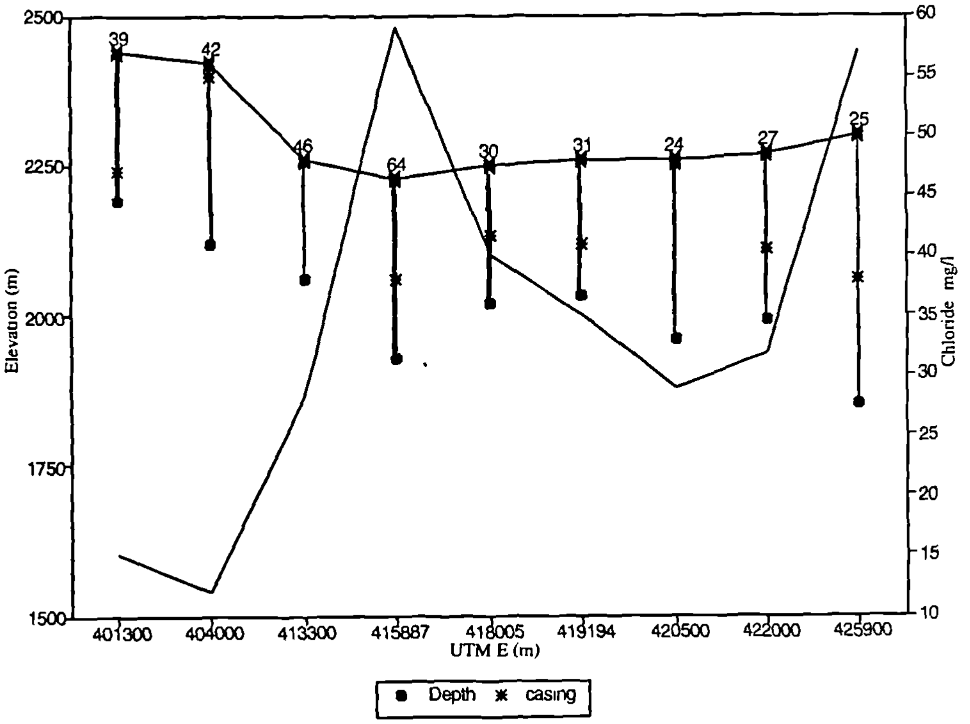


Figure 8.3 Areal distribution of Chloride ion concentration (mg/l).

(N.B. contours lines are drawn only for the Cretaceous S.S.)

This is shown in Figure 8.4 in an east-west cross section, passing along Wadi AlRawna to the middle of Sana'a plain and continuing to the western plateaux. It shows a high chloride concentration of 57 mg/l in sample 25, which is taken from a borehole that draws its water only from the Cretaceous Sandstone, although the aquifer here is buried under thick volcanic and Quaternary aquifers. As water moves towards the plain, the chloride concentration declines to 29 mg/l in sample 24, which has DO of 5.9 mg/l, is located near flood terrace deposits and probably represents recent recharge water. Chloride concentration starts again to increase, reaching 59 mg/l in the middle of the Sana'a plain (sample 64). The trend of dissolved oxygen and iron content (Figure 8.4B) in these samples support movement of groundwater toward the mountain front where a dilution by a fresh recharging water is taking place. Chloride content can increase beneath thicker alluvial deposits (e.g. sample 64), however, it should emphasized, however, that samples with high chloride concentration may still represent recent recharge water as indicated from their tritium content (see subsequent sections) and which originated from irrigation return.

In general most samples taken from wadi bottom show mixed water from the shallow alluvial and consequently have different water type (see below) or more nitrate concentration (sample 6 in Wadi Rujam), only sample 13 in the middle of Wadi Alsir has Ca-HCO_3 water type, devoid of nitrate and with high DO value. The sample was taken from a borehole tapping the cropping Sandstone. This indicates the direction of groundwater movement within the wadi bottom and support what has been used during the construction of groundwater model for shallow aquifer, (chapter 6).



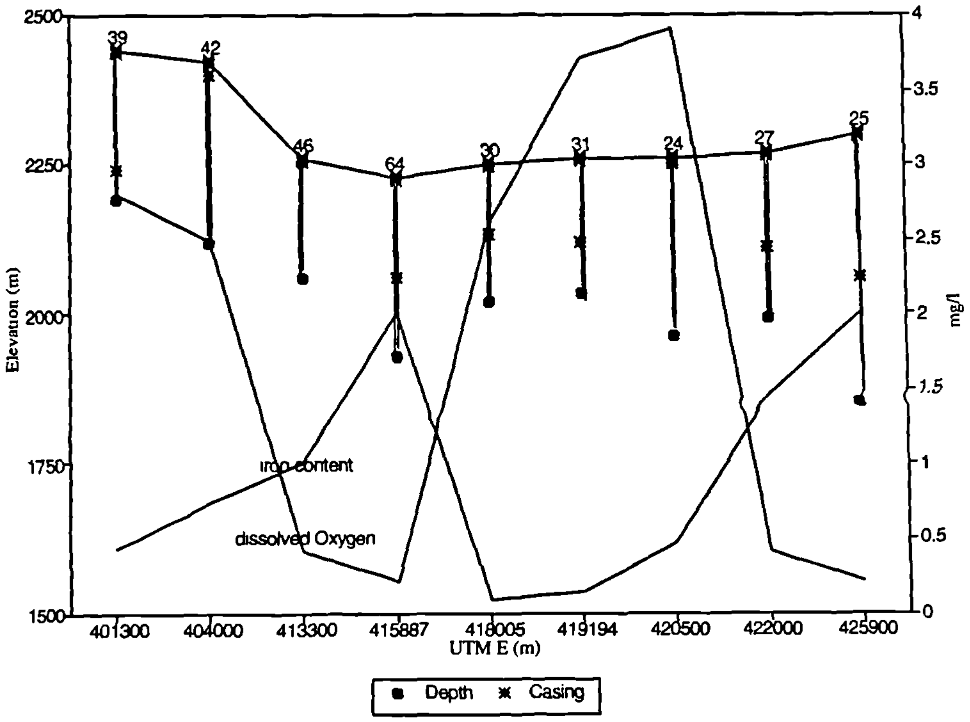


Figure 8.4 East-West hydrochemical cross sections, (A) chloride concentration, (B) iron content and dissolved oxygen (mg/l).

The other major water types are those dominated by **Calcium-indiscriminate anions or Calcium-Sulphate** and are related to dissolution and/or mixing. The simple dissolution water represents old, confined water, with high ion concentration and high iron content. An example of this water type is sample (11) upstream of Wadi Alsir. It has the highest ion concentrations, TDS of 1059 mg/l, chloride 170 mg/l, high iron content of 2 mg/l and is devoid of nitrate and dissolved oxygen. This water is found at the far eastern part of the basin, beyond which the Cretaceous Sandstone is covered by Tertiary volcanics and probably without any hydraulic connection between the two aquifers. In these areas, the locals use dug-wells for water supply as the shallow aquifer has fresher water.

The distribution and evolution of water chemistry over the basin is clearly controlled by tectonic structures and the volcanics. Mixing of water from more than one aquifer may occur along fracture zones which provide high vertical permeability. However, more visible is mixing within boreholes, as most of them are open over a considerable thickness of aquifer or over more than one aquifer. The velocity of water flow increases markedly as the abstraction borehole is approached. Mechanical dispersion, which is directly dependent upon velocity should become an increasingly effective mechanism for vertical mixing of groundwater flowing to a pumping well. Mixing is also facilitated by the strong component of vertical flow within the cone of depression and by change from laminar to turbulent flow close to the borehole.

The processes during mixing are related to solubility-changes as a result of pH or redox change. When mineral solutions of different composition are mixed, the molalities and activities of individual ions in the mixture are often non-linear functions of their end member values. This non-linearity is particularly significant in determining mineral saturation levels (Wigley and Plummer, 1976) and may cause well clogging. The other effect of mixing is a change in the redox condition by causing potentially marked disequilibrium conditions in the groundwater sample.

Most of other samples from Wadi AlSir, indicate the mixing of near surface high DO, Eh, NO_3 water with deeper more reducing groundwater, containing no DO, no or low NO_3 and elevated Fe. These samples vary from one to another depending upon the contribution in quantity and quality of each layer. In general, mixing between groundwater from the Quaternary deposit or/and more than one layer of the Cretaceous Sandstone is found in Wadi AlSir, where the Cretaceous Sandstone outcrops or is near to the surface. Sample 10 is an example of mixing within the Cretaceous Sandstone, with elevated iron (>2 mg/l) and chloride (90 mg/l) and TDS (665 mg/l), Eh of -.126 V and low nitrate (2 mg/l). This is supported by the location of the borehole and its depth (260 m) and shallow casing (12 m). An example of mixing with Quaternary deposits is sample 15, which is located near the main wadi AlSir channel near village Alsubaha, and has Eh 0.06V, TDS 767 mg/l, chloride 137 mg/l, nitrate 22 mg/l and iron of less 0.8 mg/l. The chloride concentrations of these samples are shown in Figure 8.4.

Evidence of mixing with the volcanics was found in samples taken from boreholes in Wadis Rujam and AlRawna, where the Sandstone is covered by the volcanics, as described below.

Sodium-Bicarbonate dominant water type is found in Sample (1) from the spring at the slope of AlQadam mountain, and its origin is related to the volcanics. The spring drains Tertiary volcanics that cap the Cretaceous Sandstone and indicates that there is little or no hydraulic connection between the two aquifers in this area. However, the presence of the sodium with calcium in water sample 2, which is taken from a deep borehole tapping the Cretaceous Sandstone at the foot of Jabal AlQadam near the spring suggests that the water has been affected by the volcanics. The long residence time for this water can be read from high TDS value (754 mg/l), and chloride concentration (97 mg/l), compared to other samples from the wadi, whereas the confined reducing environment is reflected in high iron (2.55 mg/l) and Eh (-.2V), with zero nitrate. Sample (4), which is located in the lower reaches of wadi Rujam, near to the foot of a hill but at lower altitude than AlQadam, represents a milder reducing condition to that of sample (2), which is probably due to mixing with more fresh recharge water similar to that of sample 5.

The presence of sodium with calcium in water samples (26 and 29) also indicates the involvement of the volcanics in the evolution of these samples. However, in this case, it is difficult to distinguish whether this mixing is through boreholes or through natural hydraulic interconnection between two aquifers. The chloride concentration for these samples is also shown in Figure 8.4, in different colour. The low TDS value of 430 mg/l of water sample (26) suggests that ion-exchange is responsible of the sodium which is more likely to be originated from dissolution of igneous minerals. Although there are insufficient data to exclude this, the lowest TDS can be attributed to the least soluble aquifer material of the volcanic rock (Alderwish, 1992).

Sample 20 from the mouth of Wadi Alsir, is probably taken from the Amran limestone, as this area represents the limit of the Cretaceous Sandstone.

Calcium-chloride dominant water is found in only one sample (9) which is taken from the shallow alluvial aquifer in Wadi Alsir. Although this water might have been polluted by cement (Lloyd and Heathcote, 1985), the well is located in a densely populated area, and comparison with samples taken from boreholes (i.e without cement) within Sana'a city supports the explanation that this water is contaminated by human waste.

8.3.2 Western Plateaux

This covers Wadi Dhar, Hamdan and Darwan areas and is represented by 14 samples from the Cretaceous Sandstone and the volcanics. The samples are drawn in expanded Durov diagram in Figure 8.5, and can be grouped into three water types;

1 Calcium-Bicarbonate water
2 Sodium-Bicarbonate water
3 Calcium-Sodium-Bicarbonate water

5 samples (35, 37, 46, 47 and 80) are dominated by **calcium and bicarbonate** ions, with nitrate concentrations of 13, 5, 15, 24 and 14 mg/l, respectively. Except for sample (80), all the samples were taken from boreholes tapping only the Cretaceous Sandstone aquifer and probably indicate recharging water and unconfined conditions.

Three samples (34, 36 and 38), taken from boreholes in the lower reach of Wadi Dhar, differ from the first water type by the presence of a considerable concentration of magnesium ion. The presence of the magnesium indicates the influence of the volcanics on this water, as Mg probably originated from igneous minerals.

The chloride concentration distribution, is drawn in Figure 8.3 and hydrochemical cross section is illustrated in Figure 8.4. The chloride concentration increases towards the plain, that is in the same direction of groundwater movement. Considering the chloride distribution over lower reach of Wadi Dhar (i.e. samples 34, 36, 37, 38, 47 and 80), samples collected from near the wadi channel have the lowest chloride concentration and it increases away from the channel. The chloride concentration also increases in the downstream direction of Wadi Dhar.

A sodium-Bicarbonate water type is present in sample 39 with a TDS value of 340 mg/l. The sample was taken from a borehole that taps the Quaternary volcanics in the upper reach of Wadi Dhar (Figure 8.4). Sample 41, with a considerable concentration of Calcium besides the sodium has higher TDS of 402 mg/l and DO of 2.6 mg/l. Its location near the Wadi Hamdan channel indicates recharging water.

Similar conclusions can be drawn from the variability in the rates of igneous mineral weathering, which result from the significantly differences between equilibrium conditions at the time of silicate mineral formation and those at the surface. Goldich (1938) suggests a series similar to "Bowen reaction series" to list the rank of weathering. Garrel (1976) indicates that the relative abundance of a mineral in an aquifer has an effect on water chemistry. For example, the rate of alteration of hornblende in a rhyolite is greater than that of plagioclase feldspar (on the basis of normative mineral calculations), even though the calculations indicate that plagioclase makes a larger contribution of ions to the reconstructed water chemistry

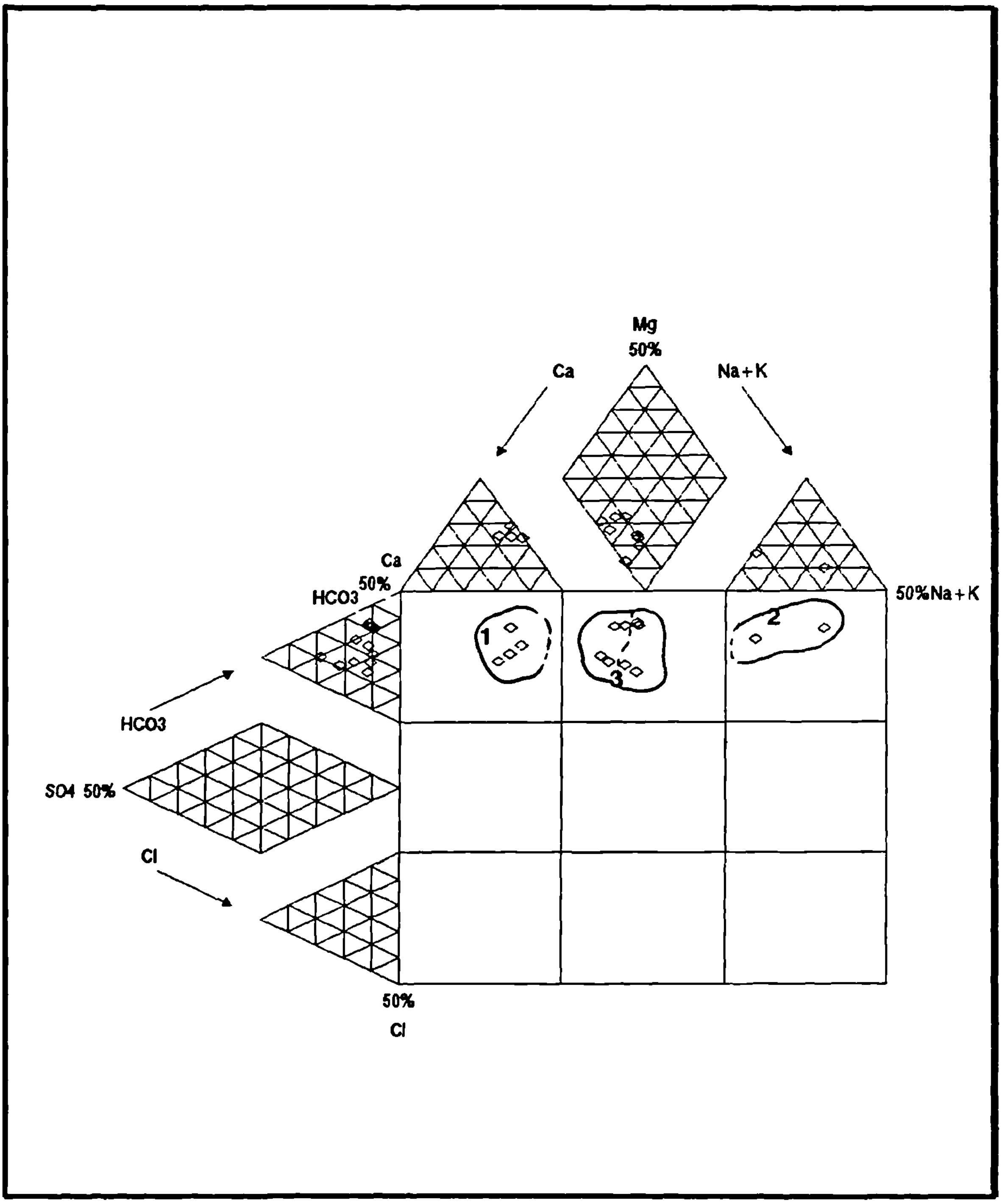


Figure 8.5 Expanded Durov diagram for groundwater of Western plateaux.

These observations, and the fact that the predominant mineral in the rhyolite is plagioclase, indicate that dissolution of minerals that constitute a large percentage of the parent material (but are less reactive) can contribute to water chemistry.

Hydrochemically, if the area contains strata of both acidic and basic volcanics, it can be said that Ca and HCO_3 ions are dominant in the fresh recharge water, and Na concentration increases with the residence time. This conclusion is drawn from the stability series of the feldspar minerals, in which the plagioclase is less stable under surface conditions than potassium feldspar. Even within the plagioclase series, the calcic plagioclase is less stable than the sodic-plagioclase. However, when sodic-plagioclase (feldspar mineral) dissolves, the water becomes more alkaline (PH value > 8.5) due to the consuming of hydrogen ion, as soon as the CO_3 concentrations are high, calcium concentration remains low, since saturation with calcite is rapidly reached. This may explain the low concentration of calcium in the old water.

Calcium-Sodium Bicarbonate water types are common in the western plateau, and represented by samples 40, 42, 44 and 45. Although these samples have similar water type, the location, chloride concentration and nitrate concentration are different. Whereas samples 40 and 42 have chloride concentration of 12 mg/l and no nitrate (volcanic aquifer), samples 44 and 45 (mixed water) have chloride concentrations of 67 and 35 mg/l and nitrate of 24 and 11.4 mg/l, respectively. Although 44 is located upstream of sample 45, the high chloride and nitrate in 44 are probably a result of village waste recycling. Hence a dilution of this water is probably taking place. The direction of groundwater movement which is toward the plain, can be traced by comparing samples (43) and (45).

8.3.3 Central Plain

Groundwater in the central plain was sampled mainly from the volcanics and Quaternary loose deposits aquifers. Only sample 64 was taken from a borehole tapping the Cretaceous Sandstone aquifer. Figure 8.6 shows the Expanded Durov diagram for samples collected from Sana'a plain. Four water types can be identified;

1 calcium-bicarbonate water
2 sodium-bicarbonate water
3 calcium chloride water
4 sodium-indiscriminate anions water

Calcium-Bicarbonate water type was found in samples (51, 55, 64, 66 and 70). Excepting sample 64 which is from Cretaceous Sandstone, all samples have nitrate concentrations between (14 - 28 mg/l) and dissolved oxygen between 3.7 and 6.3 mg/l. In addition, the location of the boreholes, which is near Wadi alSyla channel, suggests recharge water. This can be confirmed by comparing the water type of sample 55 (borehole with 120 m depth) with that of sample 56, which is taken from a nearby, deeper borehole (250 m) and has sodium-bicarbonate water type. The vertical variability of water chemistry in the two adjacent boreholes probably indicates an additional source of recharging water for the upper part of the aquifer. As discussed above, the development of sodium bicarbonate water may be considered older than the calcium bicarbonate water.

Borehole construction information for sample (64) indicates that this borehole is tapping the Cretaceous Sandstone in the plain and it is the only sample which penetrate this aquifer in the middle of the plain. This is supported by the high iron content of 1.93 mg/l, low Eh of -.157 V and zero dissolved oxygen.

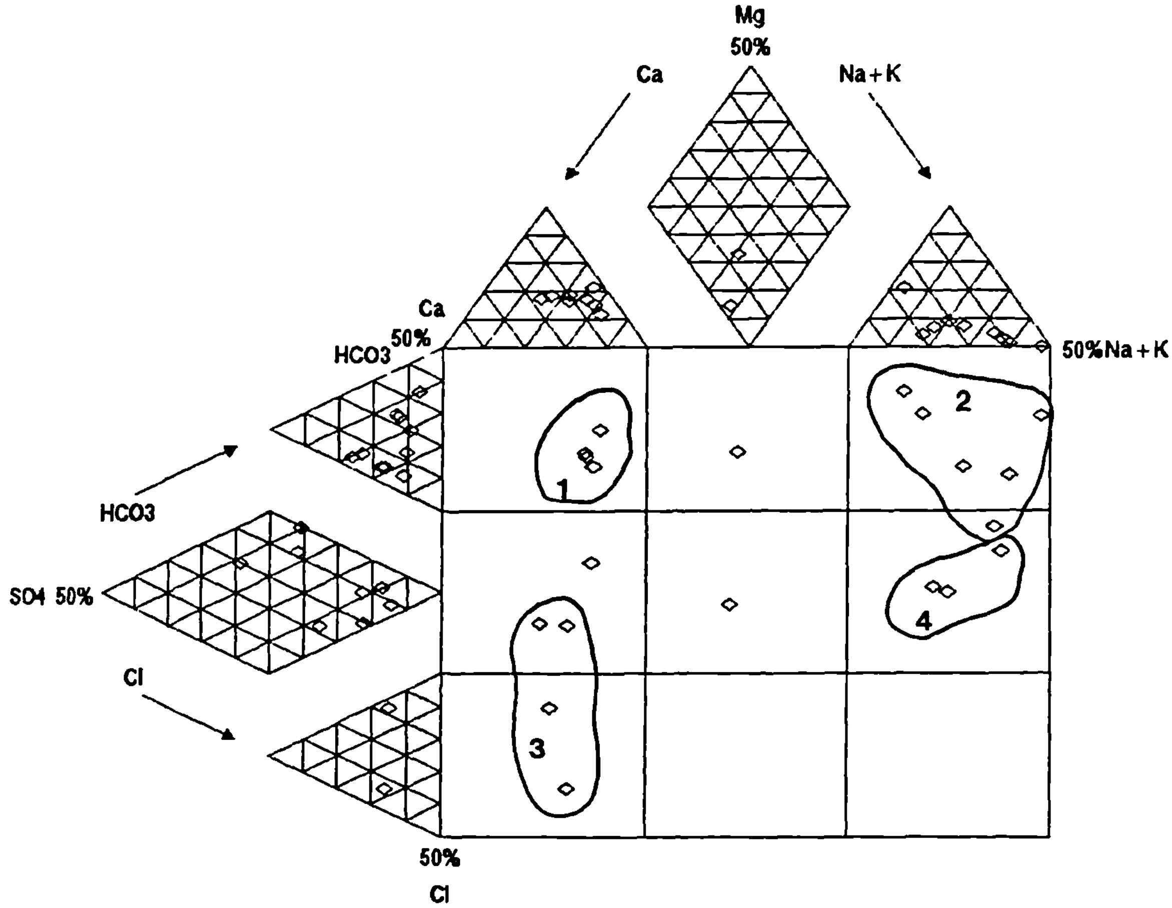


Figure 8.6 Expanded Durov diagram for groundwater of central plain

Samples 65, 76 and 78 all have calcium bicarbonate water type with significant concentrations of sodium ion. The low TDS of less than 400 mg/l indicate the origin of this water.

Samples (48, 52, 53, 54, 56 and 79) are all of **Sodium-Bicarbonate water type,** and indicate water from volcanics. The common feldspar minerals that made igneous rocks are orthoclase and microcline, which have the formula $KAlSi_3O_8$ and the plagioclase series ranging from albite $NaAlSi_3O_8$ to anorthite $CaAlSi_3O_8$. Moreover some sodium may be present, substituting for potassium in orthoclase and microcline (Hem, 1985).

Samples located near the city, which draw water from both shallow and deep aquifers have higher nitrate and chloride concentration (e.g. 53, 54, 56). Those from the border of the city, which withdraw their water from the deeper part of the aquifer have less chloride and no nitrate (e.g 48 and 52).

Samples (49 and 50) have high concentration of **sulphate ions**. The presence of sulphate in these samples can be related to oxidation of pyrite according to;

$$FeS_2 + H_2O + 3.5\ O_2 = Fe^{2+} + 2H^+ + 2SO^{-2}_4$$

and pyrite was reported in that area by Mosgiprovodkhoz (1986), (see section 3.3).

The equation can be demonstrated by comparing the chemical composition of the two samples. Sample 49 with higher TDS 358 mg/l, higher dissolved oxygen 3.6 mg/l, higher sulphate 85 mg/l but lower iron content. Sample 50 has TDS value of 256 mg/l, and dissolved oxygen of 1.8 mg/l and sulphate concentration of 49 mg/l but higher iron content of 1 mg/l. The high TDS value can be explained by the hydrogen ion released by the oxidation reaction which increases the aggressiveness of the water to attack and dissolve aquifer material.

6 samples are dominated by **calcium chloride water type**. 5 of these samples (57, 58, 59, 60 and 61) were collected within Sana'a city, and have probably been affected by recycling of foul sewage water. However, the effect is different depending upon the location and depth of the borehole. Sample (68) is taken from dug-well located about 1 km from AlRawdha stabilization ponds. The high nitrate concentration, as well as high TDS, confirms the pollution of this water.

Samples 67, 69, 71, 73, 74 and 75 are all dominated by **sodium ion with indiscriminate anions**. This water type probably shows different degrees of influence of the urban waste disposal in AlRawdha area, depending upon the mixing with the shallow aquifer. The shallow aquifer over all this area is polluted (Alderwish and Dottridge, 1993). For these samples, a decline of the chloride concentration towards the north, i.e away from the AlRawdha can be traced and perhaps supports the influence of the sewage waste effluent. The chloride concentration for sampled boreholes is shown in Figure 8.3. However, in a previous study Alderwish (1992) found similar water type from shallow wells in the Amran Group. As the location of the present boreholes are from the northern part of the plain where the alluvial aquifer is underlain by the Amran Group, partial mixing from the Amran might explain the chemical composition of this water.

Only one sample from AlKharid spring has **calcium-sulphate water type** and probably related to dissolution of gypsum (for more details see Alderwish, 1992).

A summary of the hydrochemical trend for various aquifers present in the basin is given below.

Cretaceous Sandstone, In areas where it is overlain by thick volcanic or at zone of low permeability, the chemical composition character of that water is high ion concentration, high chloride, high iron content and devoid of nitrate and dissolved oxygen. Where the aquifer outcropping, the water is fresh with low TDS and dominated by calcium bicarbonate ions with little or no iron. Significant present of either, sodium or magnesium with calcium is probably indicate involvement of volcanic rather than cation exchange process, (see Alderwish, 1992).

Water from the Tertiary volcanic aquifer is generally has low TDS which reflect the solubility of the igneous material, and dominated either by Ca-Mg-HCO_3 or Ca-Na-HCO_3, depending upon the associated rocks, whether its acidic (felsic) or basic (mafic) rocks. The Quaternary volcanic is commonly of the former type.

Although the chemical composition of water from the alluvial should reflect the type of the sediments and its source, generally this masked by the irrigation return. (also short residence time). However, a clear spatial distribution of TDS over wadi bottom can be traced and associated with direction of the groundwater flow. Low TDS water found at upstream reaches of primary and secondary wadis. The TDS increases in the direction toward the wadi channel and toward the downstream direction.

8.3.4 Tritium analysis

^{3}H, is the radioactive isotope of hydrogen and has a half life of 12.43 years. It originates from natural and artificial sources. The concentration of tritium in water is expressed in tritium unit, TU, (1 TU is equivalent to concentration of 1 tritium atom per 10^{18} hydrogen atoms.). Tritium is generated naturally by the interaction of cosmic-ray-produced neutrons in the upper atmosphere with nitrogen atoms ($^{14}N + n \longrightarrow {}^{3}H + {}^{12}C$). The natural production of tritium introduced to precipitation and surface water is up to 5 TU (Mazor, 1991). The second source is man-made and introduced to the environment since 1952 as a result of the thermonuclear atmospheric testing. This atmospheric testing injected periodic pulses of tritium into the atmosphere so that the concentration in precipitation increased by three orders of magnitude in the northern hemisphere in 1963 above that arising from the cosmic ray source (IAEA, 1983). Since 1961 the tritium concentration has been monitored in an IAEA/WMO project at more than 100 stations in the world. A knowledge of the tritium concentration of precipitation is a prerequisite for estimating the tritium input function in a given area for interpreting tritium concentrations in groundwater. A compilation of tritium values for precipitation from 1960 to 1971 from published records of IAEA (1969-1975) from the nearest stations to the Sana'a basin, Jeddah, Addis Ababa and Bahrain, are given by Chilton (1980). Tritium levels decline after the 1963 peak with regular seasonal cycle of summer maxima and winter minima over a range of 10-200 TU. Similarly to the use of stable isotopes these variations may be used to estimate the age of groundwater samples and thereby the timing of recharge to an aquifer system.

Anthropogenic tritium has been used to provide a semi-quantitative dating approach for groundwater (Mazor, 1991):
If the tritium content of the sample is less than 0.5 TU no water younger than 20 years is present;
If the tritium content is more than 10 TU, the water of recent origin;
Water with tritium content between 0.5 and 10 TU, is likely to be a mixture of pre 1952 and post 1952 water.

The samples for tritium analysis were collected from an east-west section that traverses the Sana'a basin (Figure 8.1). The tritium content is drawn in Figure 8.7 with the chloride and nitrate concentrations. Three samples have tritium content of more than 10 TU and the other two sample have tritium content less than 9 TU.

The tritium distribution in groundwater across the Sana'a Basin supports the interpretation given in earlier sections (8.3.1/2/3), namely at far eastern part of the basin where the Cretaceous Sandstone lie under thick volcanic, no recent recharge and the water devoid of nitrate and with high chloride. Moving downstream, depending upon the location, the shallow recent recharge water mixes with the deep old water. If the location is near the channel at the downstream reaches, the resulting water would still have high chloride concentration and little or no dissolved oxygen, nitrate and iron and high TDS (e.g sample 22). This is because the shallow water had contaminated by the irrigation return flow, with maximum affect observed near the main wadi channel. Whereas if the shallow water aquifer from secondary tributaries with minimum irrigation return, more fresh water would results (e.g. sample 23).

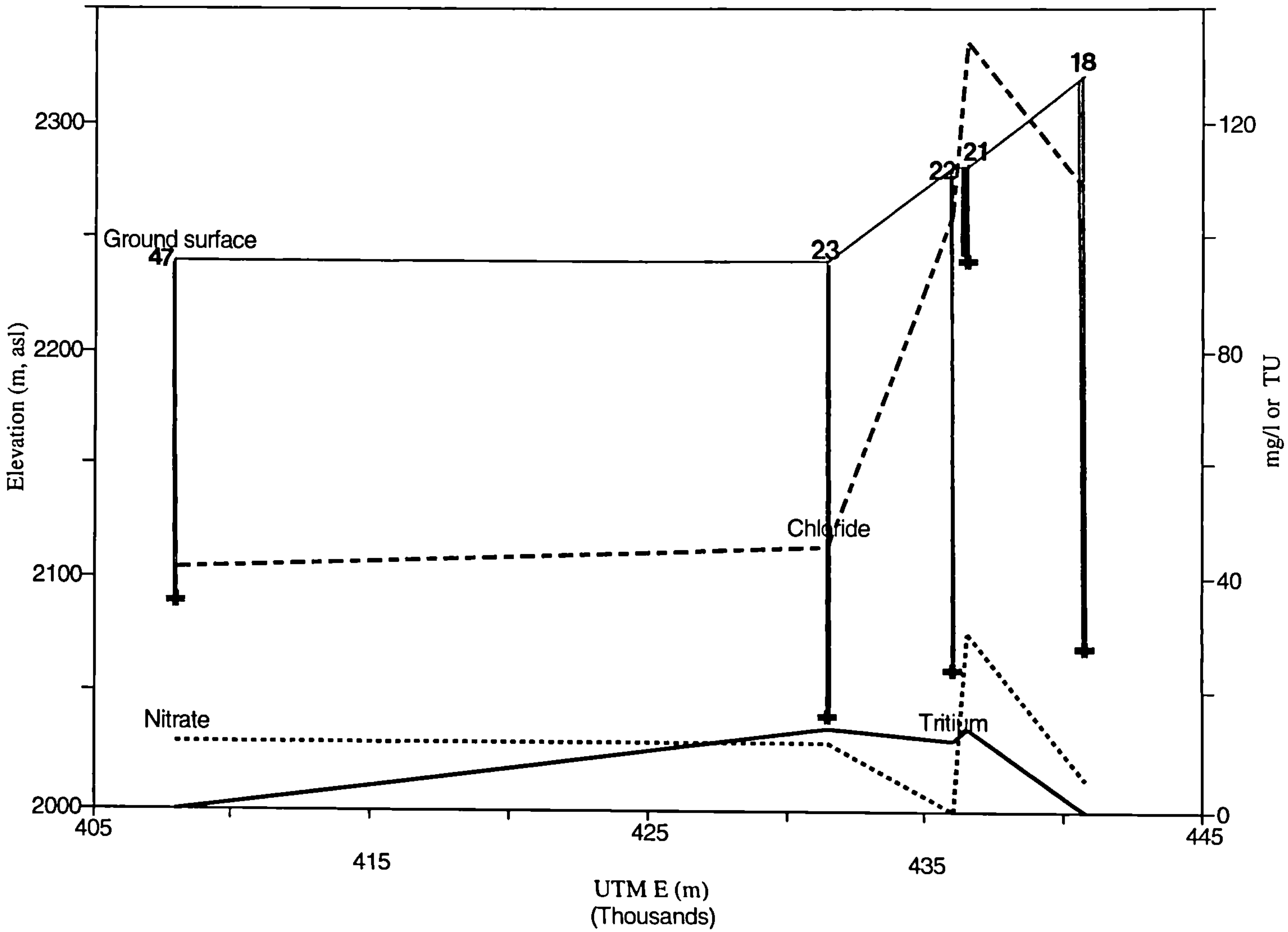


Figure 8.7 Hydrochemical cross section of tritium content, TU.

8.4 Water quality

The quality of groundwater of any region is a result of influences from; geologic, hydrologic, cultural (human activities) and perhaps other factors. Each factor has its mark on the resulting water and these marks were used to assess the various influences on the groundwater quality in Sana'a basin.

Based on the total dissolved solids, the groundwater can be divided broadly into three groups, each representing the results of particular conditions.

The first group is those with total dissolved solids greater than 1000 mg/l. This water represents water found in the deep (confined) part of the Cretaceous Sandstone, in the far eastern part of the basin. The significant character of this water is the high content of iron which is higher than the permissible WHO limit (>2 mg/l) and locals used to leave it in open tanks for 2 to 3 days, to allow iron to precipitate, before using it for domestic purposes. Distribution of electrical conductivity from the well inventory over wadi Alsir (SAWAS, pers. comm.) showed the presence of a zone of high EC, that traverses the main wadi and probably reflects a structural control, causing a low permeability zone (See Appendix F).

Water with high TDS value (>1000 mg/l) is also present in the shallow aquifer, in the middle and downstream part of wadis. It is characterized by high content of chloride and nitrate, and is a result of irrigation return flow. Return flows, some 20 to 40% of the total irrigation water delivered to the farm fields percolates through the soil to the groundwater (chapter 4). Because of evapotranspiration, its mineral content is sizeably increased (in range of 2 to 7 times). Although return flow may include agricultural chemical residuals, including toxic biocides, in the Sana'a basin this is not common because of the restricted use of these chemicals.

The second group is waters with TDS range between 600-1000 mg/l and represent mixed water between two aquifers. The variation of TDS values can be related to the type of the aquifer involved in the mixing water. The lower limit is observed when mixing occurs between deep water with the unconfined water. The unconfined water could be from the unconfined Sandstone, volcanics or wadi alluvium (at upstream part). The result out water is nitrate free, with little dissolved oxygen and little iron (e.g. sample 14). When the mixing occurs between the groundwater of the lower reaches of the alluvium, higher nitrate water is found and TDS is at the upper limit of the range (e.g. sample 23). Sample 23 with TDS value of 1000 mg/l, has tritium content of 12 TU, whereas the shallow aquifer water with TDS of 1120 mg/l, has tritium content of 14 TU.

The third group are those which have TDS value of less than 600 mg/l. They represent water from the upstream alluvium, unconfined Sandstone water along the eastern and western outcrops and water from the volcanic. The different hydrochemical character of these aquifer has been described previously, but all have good quality water of low TDS.

The upper part of the Cretaceous Sandstone aquifer, along its outcrops, does not show any signs of progressive deterioration in terms of salinity due to over-exploitation or contamination from incompatible land use in the recharge zone.

The quality of groundwater within the urban area was evaluated using the measured electrical conductivity from the urban well inventory. The electrical conductivity of the shallow alluvial aquifer varies between 480 and 2400 µS/cm depending upon the location of the dug-well, and has been contoured in Figure 8.8. The low EC is present in the southern and western border of the city, whereas the highest is found in the central and old part of the city. EC increases in the direction of groundwater movement. The electrical conductivity measured for boreholes is also shown in Figure 8.7. The distribution has a similar trend to that of the shallow aquifer, however due to mixing, the values vary between 400 and 1300 µS/cm. Although this indicates that mixing in the aquifer is sufficient to reduce the total dissolved solids, microbiological contamination might still be a risk. However, an exercise carried out by students from faculty of engineering (pers. comm. 1995), shows that no biological contamination was recorded in any of the boreholes surveyed within the city.

The water collected from the partial sewerage system is discharged in oxidation ponds near AlRawdha, with only primary treatment. As a result of overloading of these ponds, the waste water is discharged into the wadi channel, with some reuse of effluent for agricultural purposes. The extent of pollution within the city and north of AlRawdha has been described by Alderwish and Dottridge (1993).

To control deterioration of groundwater quality due to pollution sources, it would be better to keep the concentrations of contaminating substances at relatively low levels, though not necessarily eliminating them altogether. This is because elimination of pollution altogether is unrealistic, not to mention unattainable. This statement encouraged a very simple exercise to be carried out and this attempt is described below.

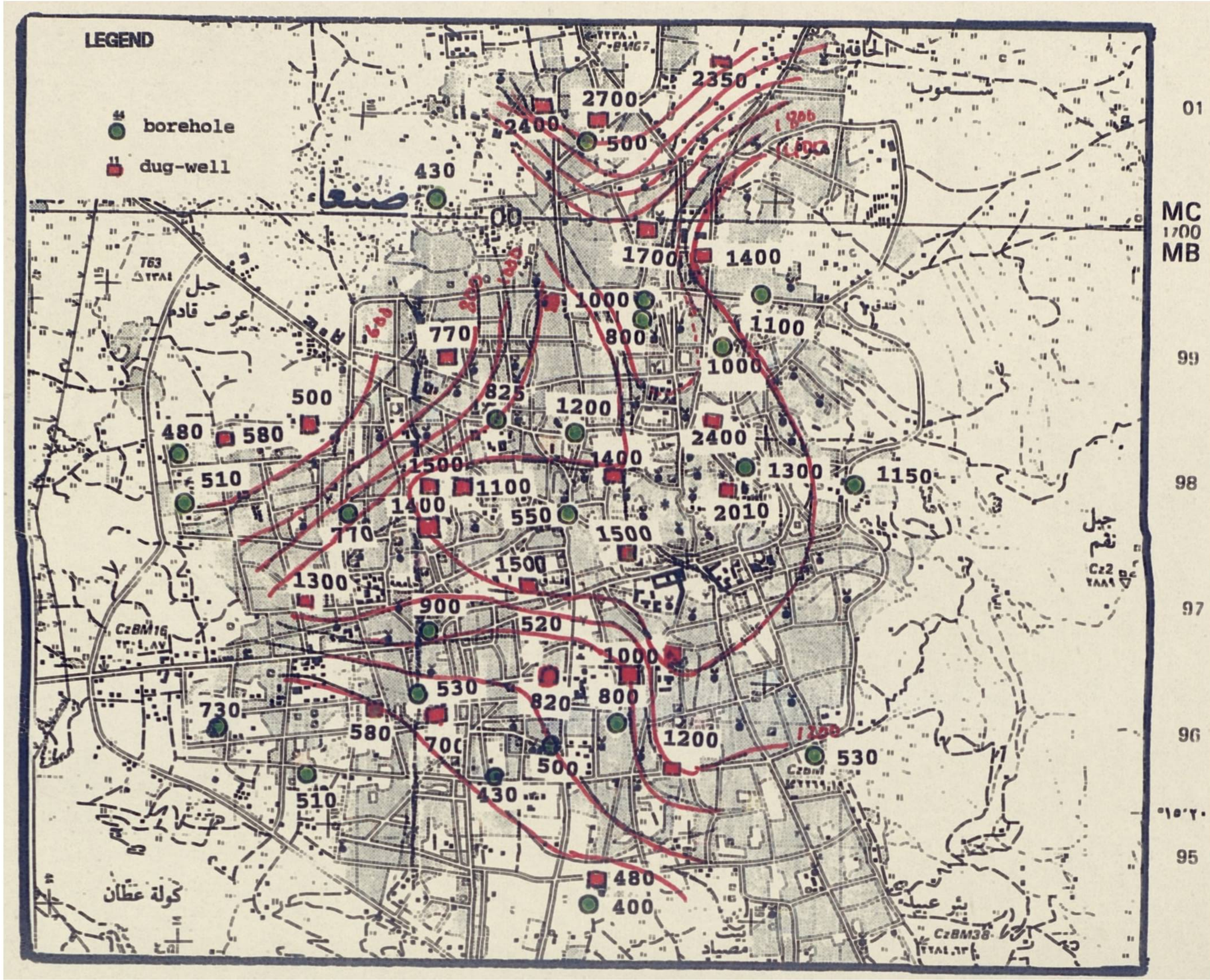


Figure 8.8 Spatial Distribution of EC over Sana'a city.

8.4.1 Recharge water quality

The potential sources of recharge in the Sana'a basin were grouped into, wadi flow infiltration which is the main source of recharge, return flow from irrigation return, and return flow through cess-pits within the urban area. The distribution of these components by area over the Sana'a basin is described in chapter 9. As these components commonly share the same recharge areas, (i.e wadi bottom), the quality of the combined recharging water from all sources that might delivered to the groundwater aquifer system has been examined. In other words, this attempt was restricted to the quantity and the total dissolved solids of the recharging water, without considering any chemical processes that would occur between the recharge surface and the groundwater table. However, it is believed that the results can show approximately the likely distribution of the water quality over the basin.

A simple procedure was used, which involved summing the product of the average total dissolved solid of the recharging water and its annual volume. The average TDS of the 80 samples analyzed in the Sana'a basin during the present study was assumed to equal the total dissolved solids of applied groundwater for irrigation, that is 595 mg/l. The TDS of rain/wadi flow water is averaged from Mosgiprovodkhoz (1986) data as 132 mg/l. The total dissolved solids of irrigation return flow is ranges from 2 to 7 times of the TDS of the applied water. The higher TDS is found in drier years, and the lower in wet years. The final results of mixing of the wadi recharge and the irrigation return flow for various hydrogeological zones, after a period of 20 years (1974-1993) is summarized in Table 8.1.

Table 8.1 Tentative results of the likely total dissolved solids of recharging water over hydrogeological zones.

Zones	TDS mg/l
Zone A	1373
Zone B	1096
Zone C	1303
Dhar	744
Hamdan	571
Gabir	1143
Hizyz	1063
Akhwar	1019
Gyman	978
Asfal	1011
AlRawna	1069
Rujam	1482
AlSir	1141
AlMahjir	727

A similar procedure was applied for the urban recharge. TDS of cess-pits was 2400 mg/l (Al-Eryani et al 1991), leakage from supply was 500 mg/l, and assumed return from industries 1000 mg/l. The resulting recharged water over 20 years has a TDS value of 1800 mg/l.

It should be stressed that, these results are only tentative, and several other factors must be included before a real total dissolved solids of the recharging water may be obtained. A serious attempt to do that is recommended in chapter 10.

9 SANA'A BASIN GROUNDWATER REGIME

9.1 Introduction

The inter-relationship of groundwater recharge, abstraction, and groundwater level has not been examined thoroughly before, probably because sufficient data for such analysis were not available. As the present study made information concerning groundwater recharge for the basin available, a verification of the inter-relationship was attempted.

A summary and brief description of the final results of various recharge components and their distribution by area over the Sana'a basin are discussed in section 9.2. The basin was divided on a similar basis to those used in the indirect recharge estimation (Figure 2.1); each area was given similar code "name" and considered as a separate hydrogeological zone. Then the distribution of groundwater abstraction between these zones, as evaluated from the total abstraction over the basin, is described in section 9.3. This allows annual abstraction for each zone to be compared with the annual recharge and hence clarifies groundwater resource potential for each zone (section 9.4). The available monitored groundwater levels were compared with recharge events, and then with net recharge after being corrected for abstraction. Findings are described in section 9.5.

9.2 Distribution of groundwater recharge

The various components of groundwater recharge over the Sana'a basin for the last 20 years were estimated in previous sections. A summary of the total groundwater recharge over the basin for each component is given in Table 9.1 and illustrated in Figure 9.1

Table 9.1 Annual total groundwater recharge components over Sana'a basin

year	Wadi recharge MCM	Irrigation recharge MCM	Urban recharge MCM	Total Recharge MCM
1974	42.575	6.233	2.319	51.127
1975	89.397	7.012	2.595	99.003
1976	17.790	7.790	2.870	28.449
1977	129.000	8.568	3.145	140.404
1978	8.738	9.346	3.421	21.506
1979	6.051	10.125	4.370	20.546
1980	23.141	10.904	6.936	40.980
1981	33.138	11.682	7.201	52.021
1982	82.908	12.461	8.280	103.649
1983	120.000	13.239	9.073	142.733
1984	27.746	14.018	11.300	53.063
1985	24.496	17.474	11.051	53.021
1986	50.741	30.963	8.854	90.558
1987	5.528	22.450	9.552	37.530
1988	19.323	17.408	11.297	48.028
1989	13.433	25.322	11.747	50.502
1990	3.048	22.337	12.663	38.048
1991	2.853	16.262	14.065	33.181
1992	31.505	61.509	17.472	110.486
1993	38.896	46.678	16.849	102.423
average	38.472	18.589	8.753	65.863

The wadi recharge is very erratic, varying between 129 MCM in 1977 to 2.8 MCM in 1991, with an average of 38 MCM/year. A general declining trend of the wadi recharge can be seen over the 20 years. Out of the 20 years, 6 years have recharge below the average and 5 years below 10 MCM/year. The irrigation recharge over the period between 1986 and 1993 varies between 17.4 MCM in 1988 to

61.5 MCM in 1992, with an annual average of 30 MCM/year. For the earlier period, depending upon the irrigated area, it increases from 6.2 MCM in 1974 to 17.5 MCM in 1985. Urban recharge (representing 59% of the water abstracted for domestic and industries or 75 % of water supplied) increases from 2.3 MCM in 1974 to about 16.9 MCM in 1993. Although the increase is monotonic, reduction in NWSA abstraction in some years is consequently reflected in the recharge. The total recharge over the basin varies between 143 MCM in 1983 and 20.5 MCM in 1979 with annual average recharge of 66 MCM/year.

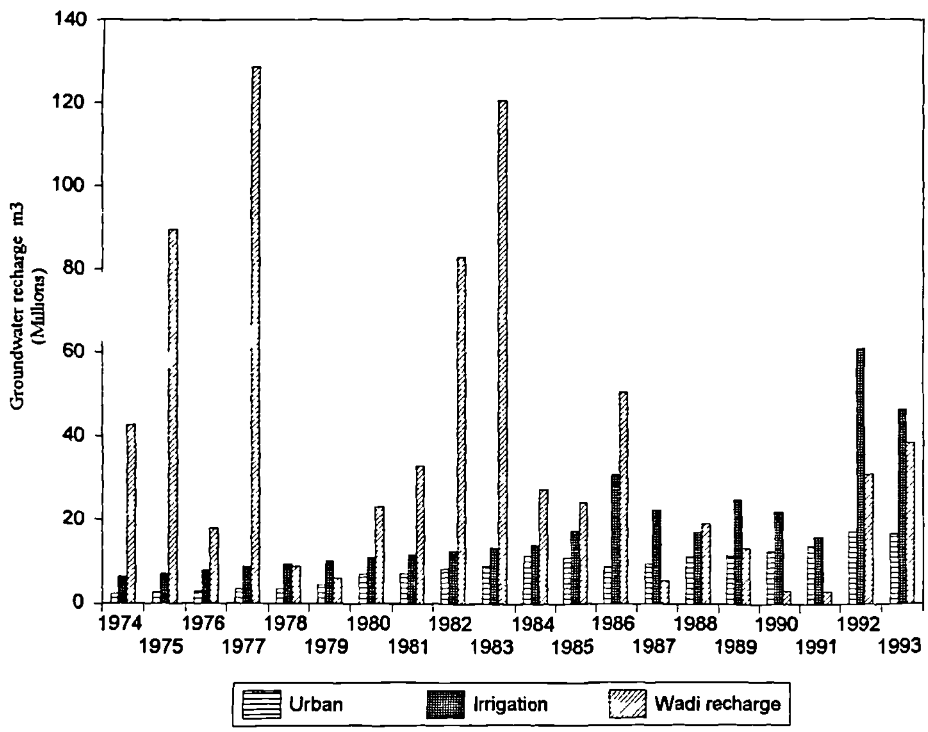


Figure 9.1 Annual recharge components over Sana'a Basin

Indirect recharge was estimated for each hydrogeological zone in chapter 6, and average annual recharge is given in Table 9.2. Total annual irrigation recharge over the Sana'a basin was estimated in chapter 4. The distribution of irrigation recharge between various zones was computed by the following relation;

$$IRZ_{i,n} = (AZ_{i,n}/AB_n)*IRB_n$$

Where IRZ is irrigation over a hydrogeological zone, AZ is irrigation abstraction over a hydrogeological zone, AB is irrigation abstraction over the basin, IRB is irrigation return over the basin and subscripts i and n represent the zone and a year between 1974-1993, respectively. The relation has been inferred from findings in chapter 4, where the amount of the irrigation return is found to be related to the amount of abstracted water for irrigation. Estimation of abstraction for irrigation for each zone is described in the subsequent section 4.3. Table 9.2 summarises the average of irrigation recharge for each zone over the period 1974-1993. Annual detailed information is given in Appendix G.

The accuracy of distribution of recharge between aquifers in Sana'a basin has been limited by the absence of information required for quantification of the inter-aquifer recharge component. Nevertheless, an approximate figure for indirect recharge to each aquifer has been calculated. This was based on the proportion of the underlying aquifers that underlie the alluvium within the wadi. Information about the relative extent of each aquifer for each wadi was derived from Mosgiprovodkhoz (1986) and is given in Table 9.3.

Table 9.2 Average annual recharge components distribution over hydrogeological zones

Hydrogeological zones	Wadi recharge m^3/year	Irrigation recharge m^3/year	Total* m^3/year
Region A	781128	975247	1756375
Region B	12725134	5173014	17898148
Region C	9882183	6199834	24835214
Dhar	5225089	1226361	6451450
Hamdan	421406	72372	493778
Gabir	270841	186503	457344
Hizyz	876959	172480	1049440
Akhwar	1222276	584804	1807080
Gyman	1180220	485099	1665320
Asfal	2232380	1000303	3232683
alRawna	660892	385538	1046431
Rujam	337337	585872	923209
AlSir	1962116	1457424	3419540
AlMahjir	742972	108468	851440
Average	38520936	18613320	65887453

* Average urban recharge is 8753196 m^3/year, occurring over hydrogeological zone C.

Table 9.3 The relative extent of underlying aquifers for various zones

Wadi	Quaternary volcanic %	Tertiary volcanic %	Cretaceous sandstone %	Amran Group %
Region A	-	-	85	15
Region B	69	-	-	31
Region C	-	42	49	9
Dhar	15	85	-	-
Hamdan	-	53	47	-
Gabir	-	100	-	-
Akhwar	-	100	-	-
Gyman	-	100	-	-
Asfal	-	100	-	-
AlRawna	-	100	-	-
Rujam	-	25	75	-
AlSir	-	2	98	-
AlMahjir	-	-	7	93

Most of the wadi recharge takes place into the Quaternary loose deposits before it percolates into deeper aquifers. Before distribution of wadi recharge between aquifers, the abstraction from the alluvium should be deducted, but it has neglected, due to the small amount of annual abstraction, which amounted to about 1.5 MCM/year (Mosgiprovodkhoz, 1986), compared with wadi recharge, and the lack of data, it has been neglected. The average annual wadi recharge to each aquifer is given in Table 9.4. The annual recharge for each aquifer is illustrated in Figure 9.2. Details are given in Appendix G.

Table 9.4 Distribution of average annual wadi recharge between aquifers.

Aquifers	Quaternary volcanics	Tertiary volcanics	Cretaceous sandstone	Amran limestone
Annual wadi recharge m^3	9,564,106	15,382,334	7,932,174	5,642,322

The highest average annual recharge is to the Tertiary volcanic aquifer, due to its large areal extent and its occurrence in the most favourable recharge areas in the south and west, with the highest rainfall and large runoff absorbing zones. The recharge value varies between 43.1 MCM in 1977 and the lowest, 2.2 MCM, in 1991, with an annual average of 14.7 MCM. The annual wadi recharge to the Quaternary volcanic aquifer varies between 32.3 MCM in 1977 to 0.4 MCM in 1991, with an annual average recharge of 9.5 MCM. The geomorphology of the terrain seems to be the controlling factor of the recharge amount over this aquifer.

The Cretaceous sandstone receives an annual recharge that varies between 26.4 MCM and 0.1 MCM, with an average annual recharge of 7.3 MCM. The lower recharge amount is probably due to its limited extent compared to the Tertiary and Quaternary volcanic aquifers. Moreover, large part the Cretaceous Sandstone aquifer occurs in a region of less favourable conditions for wadi recharge (region A) due to the lowest rainfall, and the canyon-shaped valley of the north-eastern plateau which results in narrow areas for recharge. However, it should be mentioned that hydrochemical evidence (chapter 8) indicates leakage from the Tertiary volcanic aquifer along fault zones (along zones of high vertical permeability) and perhaps also in areas with small thickness of volcanics (i.e basal basalt) through boreholes. Similar recharge conditions exist for the Amran group, which receives an annual average wadi recharge of 5.5 MCM and an additional recharge component from the Quaternary volcanics (see chapter 3).

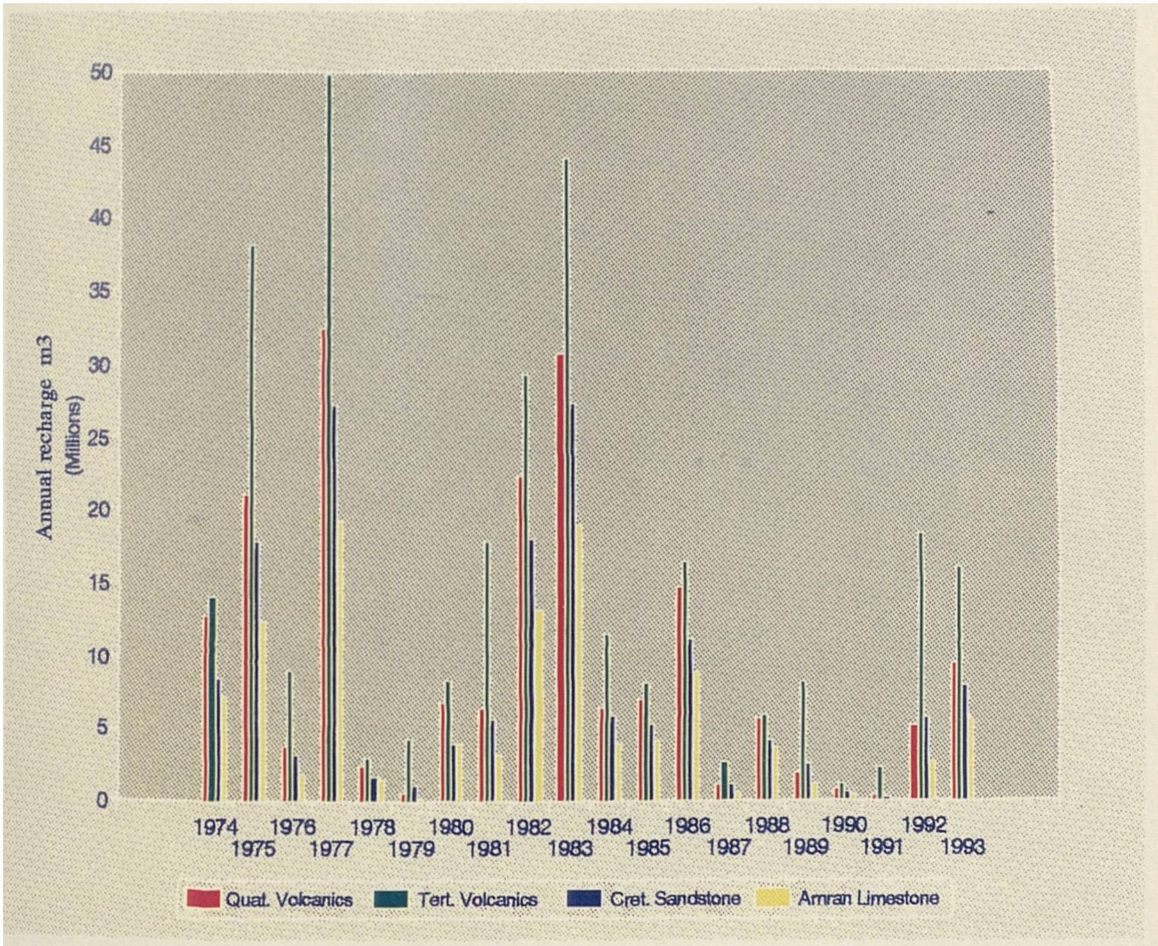


Figure 9.2 Annual variation of aquifer indirect recharge

9.3 Distribution of Groundwater abstraction

Groundwater development history and extraction for various uses was discussed in detail in chapter 1. The total annual abstraction over the basin has increased during the period between 1974 and 1993 from 24 MCM/yr to 184 MCM/yr. The urban domestic and industrial abstraction increased from 4 MCM to 29 MCM, and the rural supply from 2.3 MCM in 1974 to 5.4 MCM in 1993. The abstraction for irrigation, which represents 77 % of the annual total groundwater abstraction in the basin, increased from 14.1 MCM in 1972 to 149 MCM in 1993.

Italconsult's (1973) attempt to distribute the abstraction between two aquifers, Tawilah Sandstone and Alluvial aquifer, is questionable. This is because they assumed all urban abstraction was extracted from Quaternary alluvium, however, in their hydrogeological map (1:50,000) more than 20 boreholes into the volcanics were located within Sana'a city. Also they did not report any abstraction from the Tertiary volcanics. Mosgiprovodkhoz (1986) failed to represent the exact abstraction from each aquifer, probably because several boreholes are tapping more than one aquifer. Instead Mosgiprovodkhoz represented the production of groundwater resources by dividing the basin into several hydrogeological zones (water economic units).

In the present study, a classification slightly modified from the major classification suggested by Mosgiprovodkhoz (1986) was used for distribution of the total groundwater abstraction, so that abstraction could be extrapolated. The share of each hydrogeological zone in the total abstraction estimated by Mosgiprovodkhoz (1986) was used to estimate the abstraction for each zone, for the period between 1974 and 1993. The assumption of a constant proportion of the total abstraction in each zone during the whole period was accepted, because of the agreement between the abstraction estimated from recent well inventory data (SAWS, person. comm. 1993 and JICA, 1992) and the extrapolated abstraction for three zones. Abstraction was estimated from well inventory for Wadi Alsir in 1993 as 13.09 MCM (352 boreholes and 102 dug-wells) and the extrapolated value was 11.8 MCM. The abstraction for Wadi Rujam in 1993 was estimated as 4.6 MCM (134 boreholes and 6 dug-wells) compared with extrapolated abstraction of 4.7 MCM. The abstraction from the well inventory over most of Wadi Asfal was estimated as 7.2 MCM (162 boreholes and 48 wells) in 1991, whereas the extrapolated abstraction was 8.3 MCM. It is therefore believed the extrapolation was reasonably accurate. Table 9.5 gives the abstraction and the percentage for each zone. Detailed annual abstraction for each zone is given in Appendix G.

Table 9.5 Distribution of groundwater abstraction over various hydrogeological zone "water economic units" (compiled and modified from Mosgiprovodkhoz, 1986).

Hydro-geological zones	Total abstraction m^3/year	Percentage share %	Rural supply m^3/year	Irrigation abstraction m^3/year
region A	2822545	4.3	793695	2584435
region B	14952225	22.7	1003402	13713537
region C	29635080*	44.9	798594	11278434
Dhar	3692705	5.6	420730	3213867
Hamdan	229950	0.3	39691	186640
Gabir	559910	0.9	61918	489181
Hizyz	553705	0.8	101610	443382
Akhwar	1691045	2.6	114311	1550123
Gyman	1491755	2.3	204808	1263473
Asfal	2975845	4.5	298480	2630537
AlRawna	1132230	1.7	96847	1017566
Rujam	1693965	2.6	114311	1552997
AlSir	4236920	6.4	312769	3857479
AlMahjir	340180	0.5	53980	280846
Average	66008000		3815152	44062498

*Includes urban abstraction of 17091720 m^3

The total water abstracted for irrigation for the basin was estimated in chapter 4. Because there was no information about abstraction for irrigation for each hydrogeological zone nor the distribution of the cultivated area, irrigation abstraction for each zone was estimated from the total, after deducting the urban and rural water supply abstraction.

Abstraction for rural water supply was described in chapter 1. The distribution of the abstraction for rural supply for each zone was estimated from the population and per capita consumption of 35 l/c/d. The only data available for rural population by zones is that reported by Mosgiprovodkhoz (1986), and hence the proportion of the population in each zone in 1986 was used to extrapolate population between 1972 and 1993. By holding the per capita consumption constant, rural supply abstraction for each zone was estimated and is given in Table 9.5. The annual details are given in Appendix G.

As urban area is located within hydrogeological zone C, the annual urban abstraction between 1974-1993 as described in chapter 7, was deducted from hydrogeological zone C abstraction.

9.4 Recharge-abstraction analysis

Despite the attempts (e.g Howard Humphreys, 1983, Laredo et al 1986), it seems difficult to accurately define the storage of the Sana'a basin hydrogeological systems, so mining of groundwater can be evaluated at best from comparison between recharge and abstraction. Declining groundwater level within the wellfield area suggested groundwater mining is taking place. However, the situation for other parts of the basin is unknown due to the lack of groundwater level monitoring data. To predict present conditions, a comparison of recharge and abstraction for various zones were carried out. The results also updated information about several potential locations recommended in the past as additional sources for Sana'a city water supply (e.g. Howard Humphreys, 1983; Mosgiprovodkhoz, 1986).

Figure 9.3 illustrates the annual and cumulative difference between groundwater recharge and abstraction for the Sana'a basin between 1974 and 1993. The highest difference is 107 MCM during 1977 with recharge of 140 MCM and abstraction of 20.3 MCM. Out of the 20 years, the recharge exceeded the abstraction for 5 years, was nearly equal to the abstraction for 3 years and for the rest, recharge was less than abstraction. The highest negative difference of 120 MCM occurred in 1991. The cumulative difference indicates that only seven years have a positive trend whereas the rest generally show a negative trend. Although the declining trend extended continuously from the inflection point during year 1983 to 1993, more a steeper decline started in 1986. A deficit in the cumulative net recharge started in 1990 with 59 MCM and reached 330 MCM by 1993.

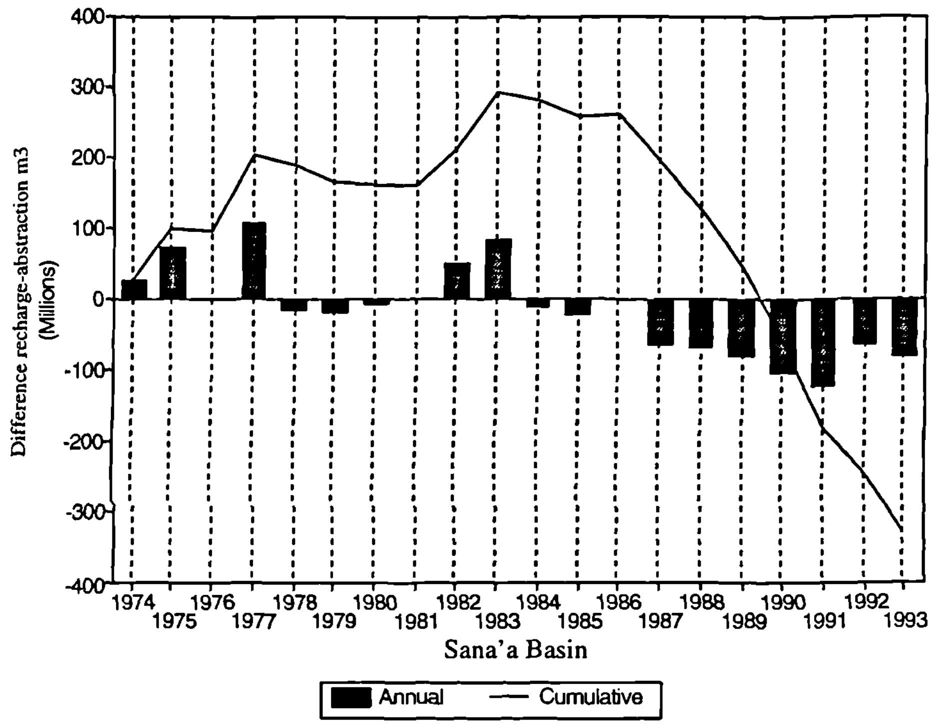


Figure 9.3 Variation of annual difference between recharge and abstraction over Sana'a basin

To examine the groundwater resource situation by area, analysis of the annual recharge and abstraction for various hydrogeological zones was performed and the results of the annual difference for some zones are shown in Figure 9.4b. The average annual abstraction, recharge and difference between recharge and abstraction for all hydrogeological zone is given in Table 9.6 and illustrated in Figure 9.4a in length unit (mm).

It should be stressed here, that unlike the analysis for the basin, subsurface inflow and outflow from each zone are significant and for accurate estimation should be included. Unfortunately no data are available and hence the results should be considered tentative.

Table 9.6 Average annual recharge, abstraction and difference for various hydrogeological units.

hydro-geological zone	Average annual recharge m^3	Average annual abstraction m^3	Difference recharge-abstraction m^3
Region A	1756375	3515453	-1759078
Region B	17898148	18622853	-724704
Region C	24835214	36910208	-12074994
Dhar	6451450	4599229	1852221
Hamdan	493778	286400	207378
Gabir	457344	697362	-240019
Hizyz	1049440	689634	359805
Akhwar	1807080	2106180	-299100
Gyman	1665320	1857967	-192647
Asfal	3232683	3706386	-473703
AlRawna	1046431	1410182	-363751
Rujam	923209	2109817	-1186608
AlSir	3419540	5277043	-1857504
AlMahjir	851440	423691	427749

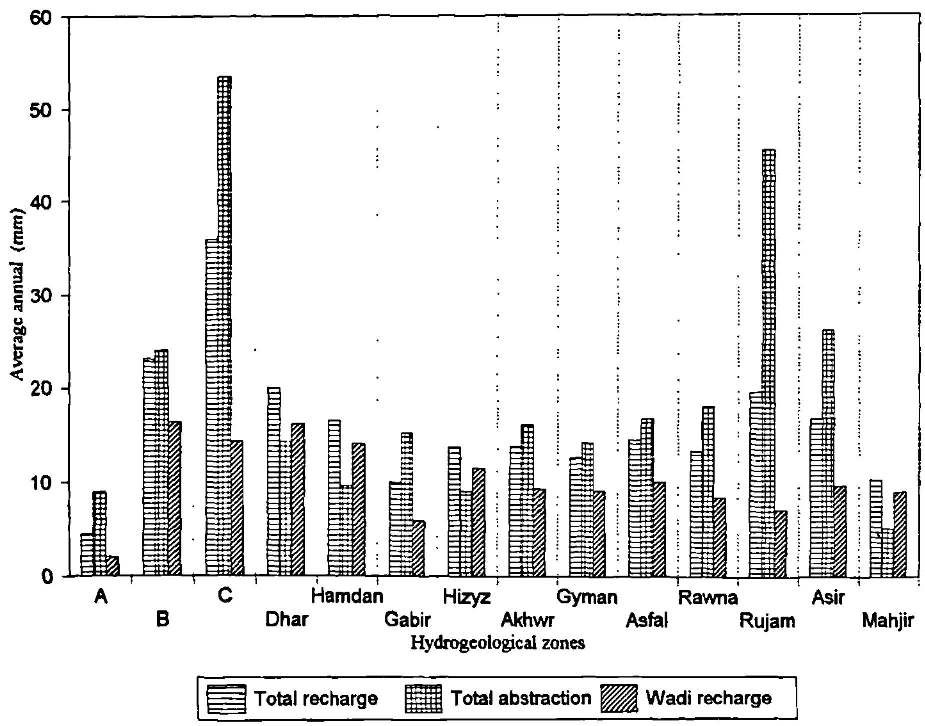


Figure 9.4a annual average total recharge, wadi recharge and abstraction for various zones, mm.

As can be seen from Table 9.6, four zones; Dhar, Hamdan, Hizyz and AlMahjir all have cumulative surplus recharge water over the period between 1974-1993. The reason for the first two wadis, Dhar and Hamdan, is because they located in the wettest part of Sana'a basin. The large extent of highland plain within Wadi Dhar creates the most favourable condition for groundwater recharge and hence it receives one of the highest amounts of indirect recharge (16.3 mm) in the basin (Figure 9.4). The cumulative surplus amount of recharge was about 30 MCM (or 20 MCM if spring discharge over 15 years was deducted) in 1993. However, since 1985, the annual abstraction has exceeded the annual recharge, apart from 1992.

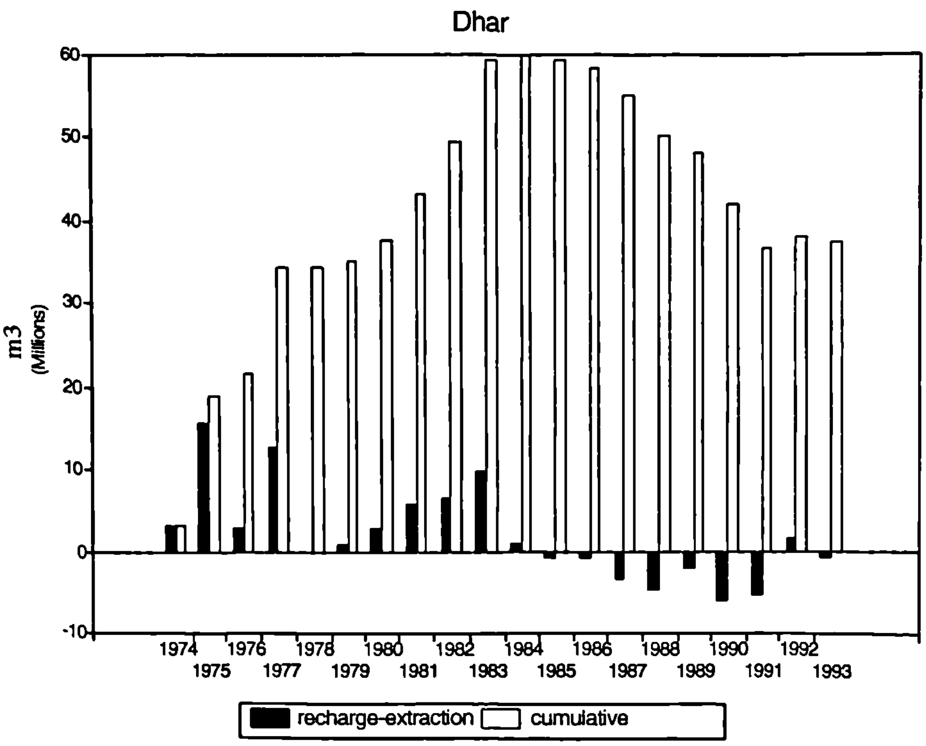
The cumulative surplus in Hizyz (6 MCM), which is located in the most southern part of Sana'a plain, is because it is composed of a large area of undeveloped flood terraces, formed by very well sorted and rounded gravel. Wadi AlMahjir receives 9.3 mm average annual indirect recharge. As the wadi is covered by quarries rather than agriculture, the abstraction is the least (5.3 mm) compared with other zones.

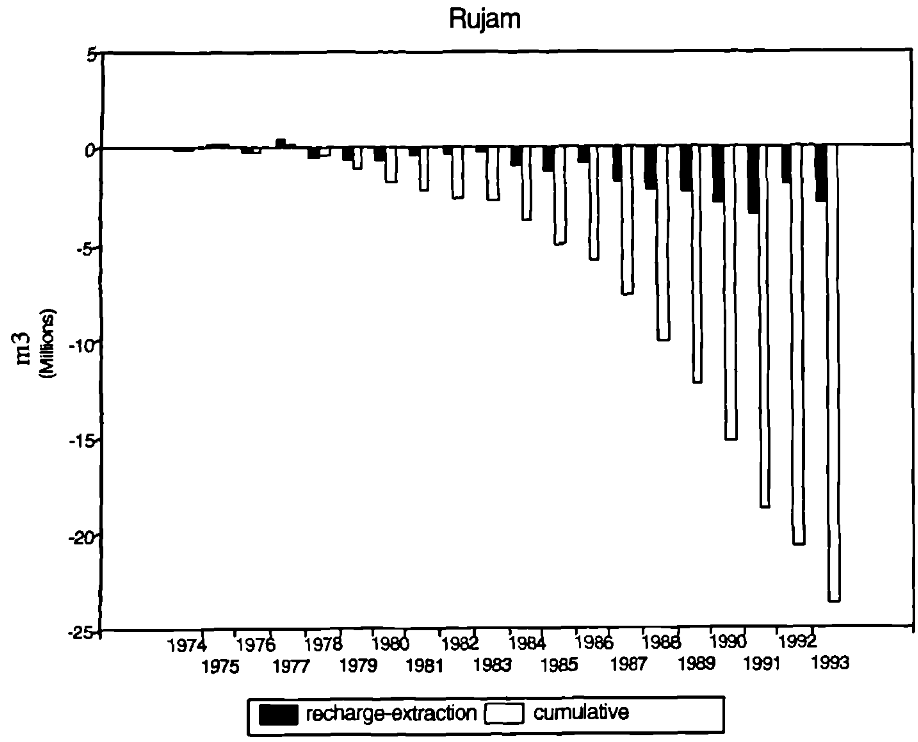
Although the cumulative difference between abstraction and recharge was negative (deficit) for the other 10 zones, the degree of deficiency varies between these zones. The highest deficit, found in wadi Rujam, is due to the next to highest abstraction of groundwater, with annual average over the catchment area of 46 mm (Figure 9.4b). The highest abstraction occurs in zone C (53 mm), where the wellfield and urban abstraction are located. However, because of the high annual average recharge of 35.9 mm (Urban and Wadi), the resource deficit started in 1988 and rapidly increased due to the high annual difference between recharge and abstraction during 1987-1991 (Figure 9.4b). In zone A with the lowest recharge of 4.4 mm, recharge has exceeded abstraction during only 4 years (Figure 9.4b) and the groundwater has been mined since 1979. This can be explained by the location of hydrogeological zone A, which is located in the driest part of the basin, and composed of three primary wadis with a very small runoff-absorbing zone which limited the amount of the infiltration through wadi bed.

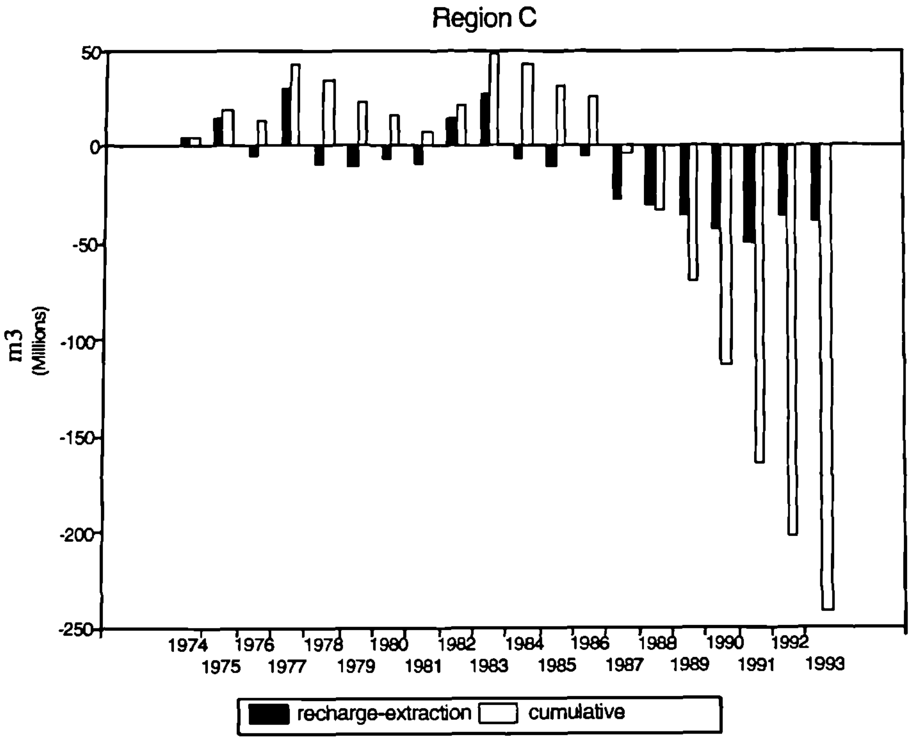
As the difference between the rainfall zones, is not large, the geographical location of the zone is not the main factor determining the surplus or amount of indirect recharge to a hydrogeological zone. Wadi Gabir which is located within the same rainfall zone as Dhar and Hamdan, has an annual average recharge of 10 mm/year (6 mm/year from wadi recharge) and abstraction of about 15.3 mm/year. Recharge exceeded abstraction in only 5 years. This is probably because most of the wadi bottom is cultivated and may be partially due to the high losses in the upland area of the catchment, as indicated by the presence of a spring at Hamil. Zone B, located in the low rainfall zone (Airport) still has the highest annual average wadi recharge of 16.4 mm. The high recharge is due to the favourable geomorphological conditions of this zone, which is covered by Quaternary volcanics and is able to absorb large quantity of wadi flows. So the cumulative deficit has started only during the last 2 years.

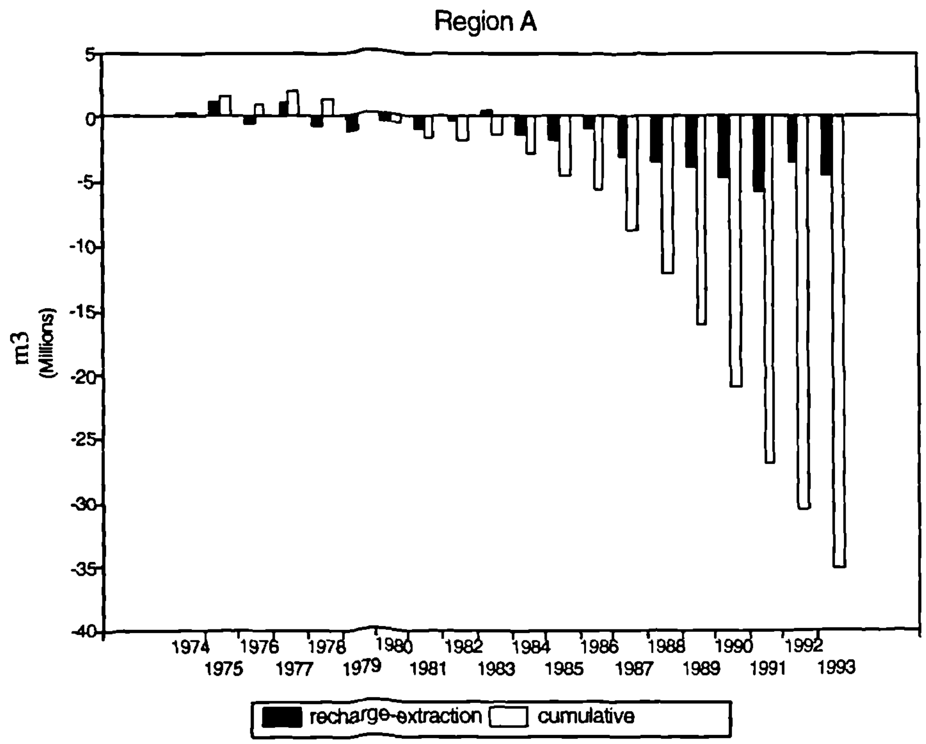
For other zones in the south-east of the basin; Akhwar, Gyman, Asfal and AlRawna, the cumulative deficit has started during the last 3 to 4 years, mainly as a result of the increase in abstraction and reduction of wadi recharge since 1984. In Wadi AlSir, the deficit started earlier in 1986, two years after the mouth of this wadi had been recommended as additional source for the city supply. The cumulative surplus in 1984 was 4 MCM which decreased to 2 MCM by 1985, as the annual abstraction exceeded the annual recharge during these two years (Figure 9.4b). The figure suggested by

Mosgiprovodkhoz (1986), for further development was 2 MCM/year with a forecast decline in water level of 100 m over 27 years. During field work in Wadis AlSir and AlRawna, it was understood from the locals that they have raised their submersible pumps by about 6 to 9 m (2 or 3 pipes) during 1993, due to the rise of the water level in their deep boreholes. Although the high rise might be also due to less abstraction from deep boreholes, still it indicates that the recharge amount varies from one year to another.




Rujam
m3 (Millions)
5
0
-5
-10
-15
-20
-25
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993
recharge-extraction
cumulative


Region C
m3 (Millions)
50
0
-50
-100
-150
-200
-250
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993
recharge-extraction
cumulative



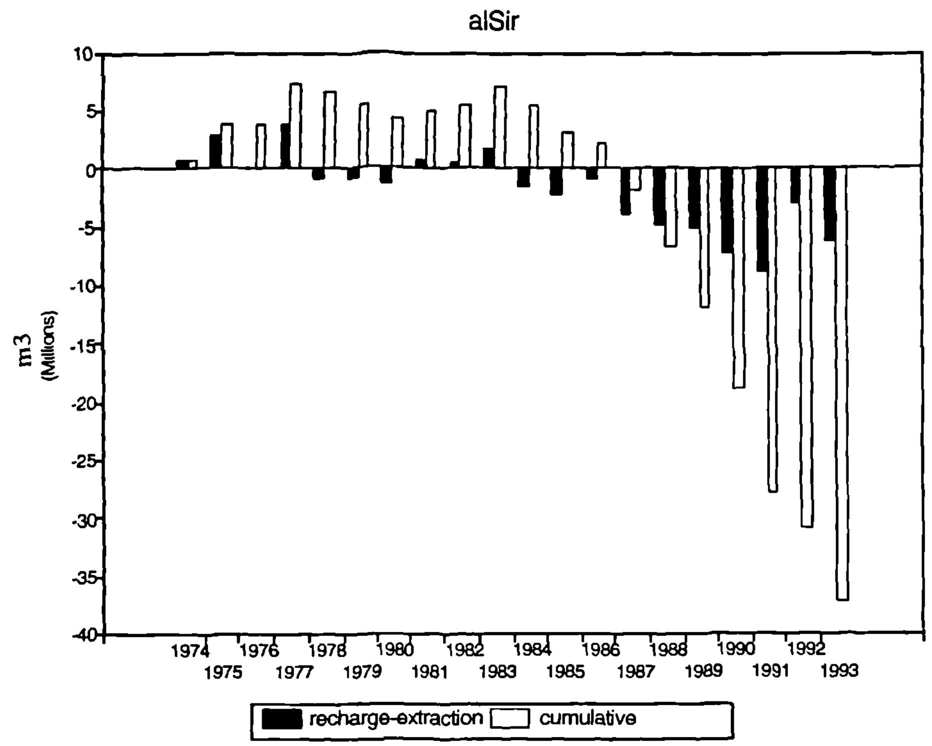


Figure 9.4b Annual difference between recharge and abstraction (i) Wadi Dhar (ii) Rujam (iii) Zone c (iv) Zone A (v) Wadi Alsir.

9.5 Groundwater level trends (response)

9.5.1 Available data

Groundwater monitoring data since 1972 are available for boreholes within the wellfield area and south of Sana'a city. Most of the monitored wells in the wellfield area tap the Cretaceous Sandstone. Three wells, "A", "B" and "C" tap more than one aquifer; Well "A" taps the Quaternary deposits and Tertiary Volcanics, "B" taps the Tertiary volcanics and the Cretaceous Sandstone and well "C" taps Quaternary deposits and Cretaceous Sandstone. The two monitored wells in the south of the city, "ST3" taps the Quaternary deposits and "SE4" taps the Tertiary volcanics. Data obtained from NWSA observation boreholes were taken from a report by Laes and Bamatraf (1991), who provided tables and hydrographs for almost all boreholes. Measurements from boreholes "ST3" and "A" were carried out during present study. Various rates of the decline of the water level in the wellfield area have been reported, but the highest rates of decline have been shown by Howard Humphreys (1980) to be due to interference from pumping wells.

Mosgiprovodkhoz (1986) presented hydrographs for 38 wells during the period from mid 1983 to early 1985. The data were obtained from 22 wells in the Quaternary deposits, 12 in the Tertiary volcanics, 1 in the Cretaceous Sandstone and 3 in the Amran limestone.

Water level measurements from 19 wells, 14 located in 4 primary wadis and 5 in Sana'a plain, were obtained during the period between March and September 1993. The hydrographs were compared with recharge events during 1993.

The main constraints of these data for recharge estimation are interference from nearby pumping, and that the measurements have been taken manually at irregular intervals using a borehole dipper. The effect of pumping is seen not only for the monitored well within the wellfield area, but also in many other wells located away from wellfield area, probably affected by nearby private production wells. The irregular time interval might lead to missing the rise in water level. Manual readings, when they taken by more than one person, may result in high systematic error. Bearing in mind these constraints, graphical analysis between recharge events and water level fluctuation was carried out and described in section 9.5.2. The description of the attempt to examine the inter-relationship between recharge minus abstraction and groundwater level trends is given in section 9.5.3

9.5.2 Recharge versus water level hydrographs

Wadi recharge is the main source of groundwater recharge in the Sana'a basin and takes place along wadi channels. The sustained, concentrated runoff along the channel and slow horizontal groundwater movement cause the water table to rise rapidly under wadi channel. Then the groundwater mound gradually declines, as water moves away to the sides and drains toward the downstream direction. In general, the closer to the wadi channel, the most rapid and highest rise of water table response to flood events occurs, and the upstream part shows a more rapid and higher rise compared to the downstream part. The rainy season is the main period of groundwater recharge and recharge through wadi beds occurs mainly during March/May and July/October. The maximum abstraction of groundwater for irrigation is during the growing season between March and October. There is little abstraction during the winter months. There is both temporal overlap between recharge and abstraction and also spatial overlap, as the abstraction in the exploited zone of the aquifers is in wadi bottoms. Figure 9.5 shows the location of observation wells. Hydrographs from Wadis Alsir and Dhar were used in chapter 6.

Hydrographs observed from three wells in Wadi alRawna and recharge events during 1993, are illustrated in Figure 9.6. The water table in well Alrahbi responded rapidly to the first rainy season recharge, with a rise of 5.52 m between 14/4/93 and 7/6/93. During the same period alJabri well showed a rise of 1.15 m, this is lower because the rise has been interrupted by pumping during June and July. Another rise in water table occurred between 10/8/93 and 23/8/93 of 2.17 m, probably representing a rapid response to the floods during early August 1993. Still, it could be due to stopping of pumping. The third well, Alsulimania showed the response of water table to recharge during the first rainy season in May. The rise of water table encouraged farmers to start pumping and readings were stopped.

For Wadi Rujam, the water table in three wells is drawn in Figure 9.7, with wadi recharge during 1993. Each of these wells shows a different response during the period of measurements. Alfurs, which is located at lower reaches of the wadi, shows a continuous rise between 1/4/93 and 16/8/93. Alhiza at the upstream reach showed a rise of 0.85 m during the first rainy season. Aljaradi, which is in the middle of the wadi, has a deeper water level of about 50 m comparing to other two wells with depth (15-20 m). It showed decline of water table between 1/4/93 until 14/7/93, then starts to rise as measured in 16/8/93.

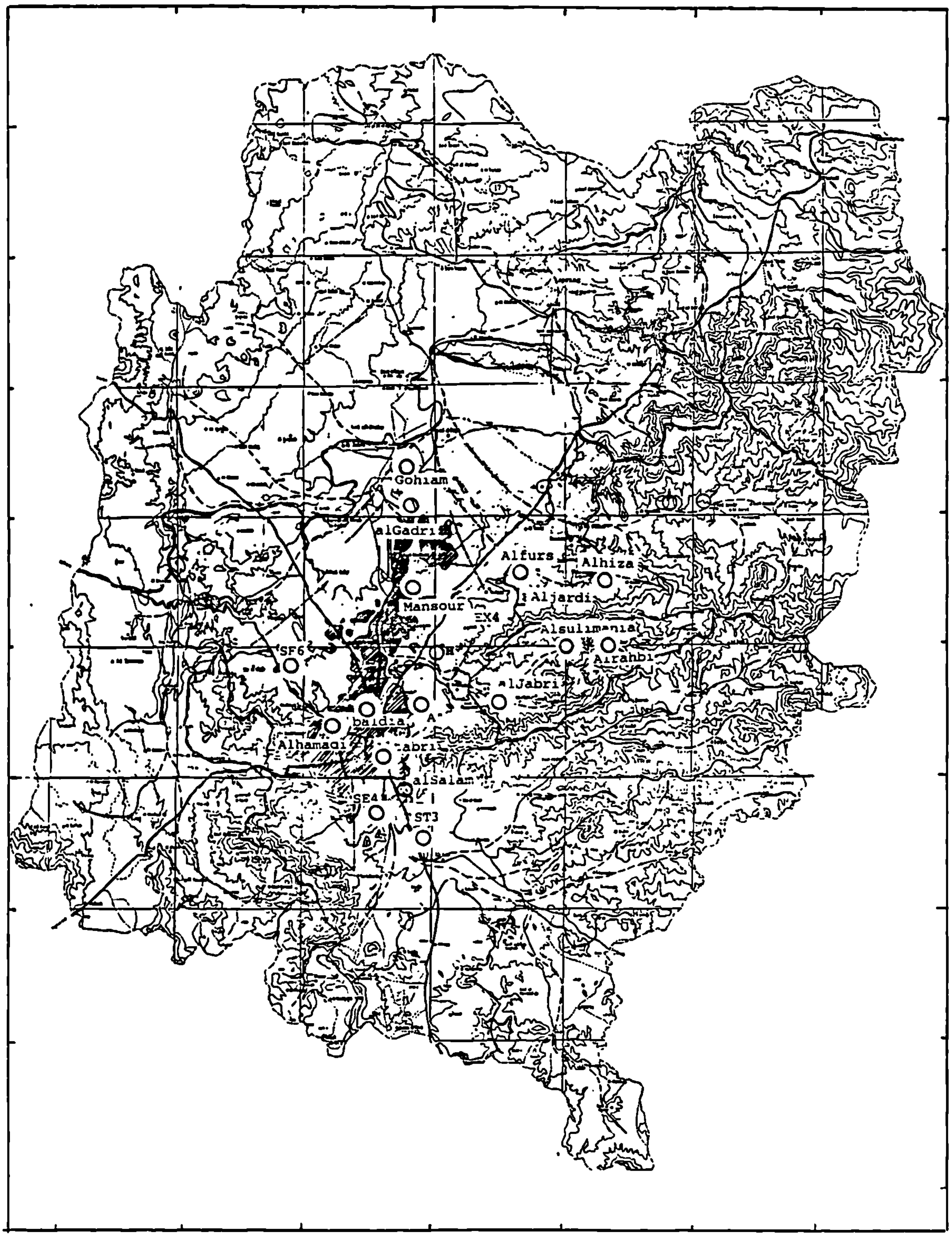


Figure 9.5 location of observation wells

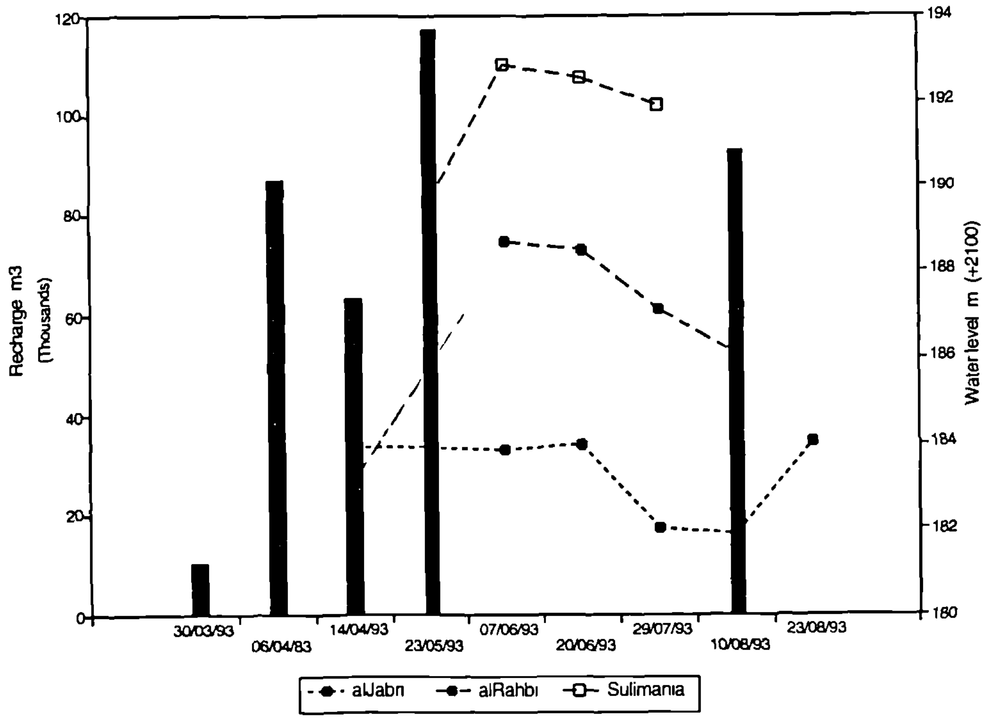


Figure 9.6 Wadi Alrawna hydrographs

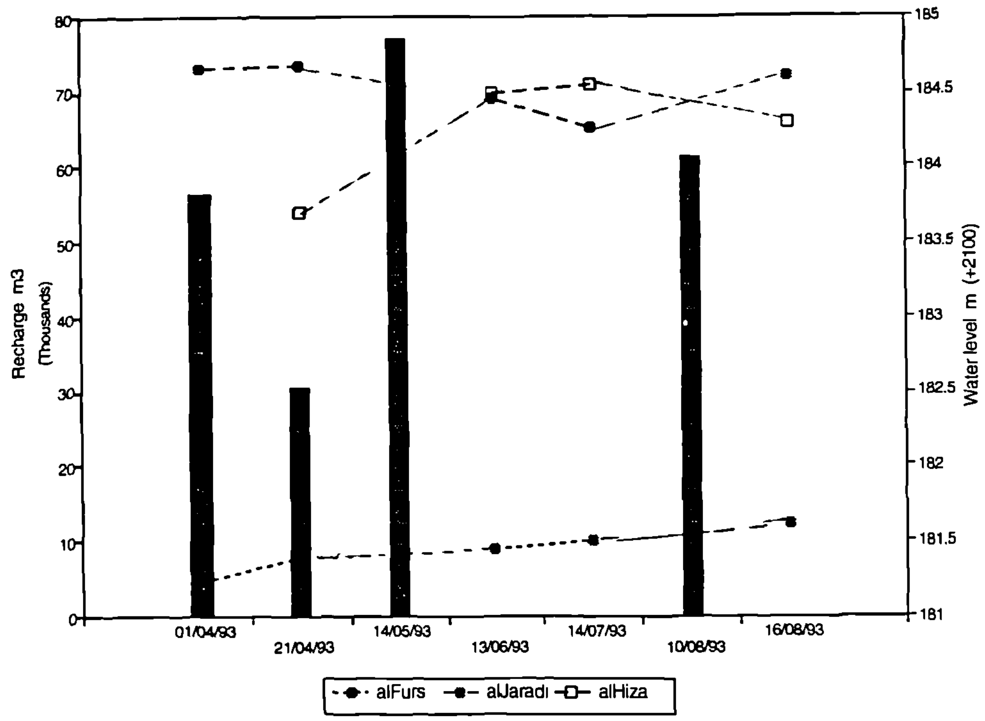
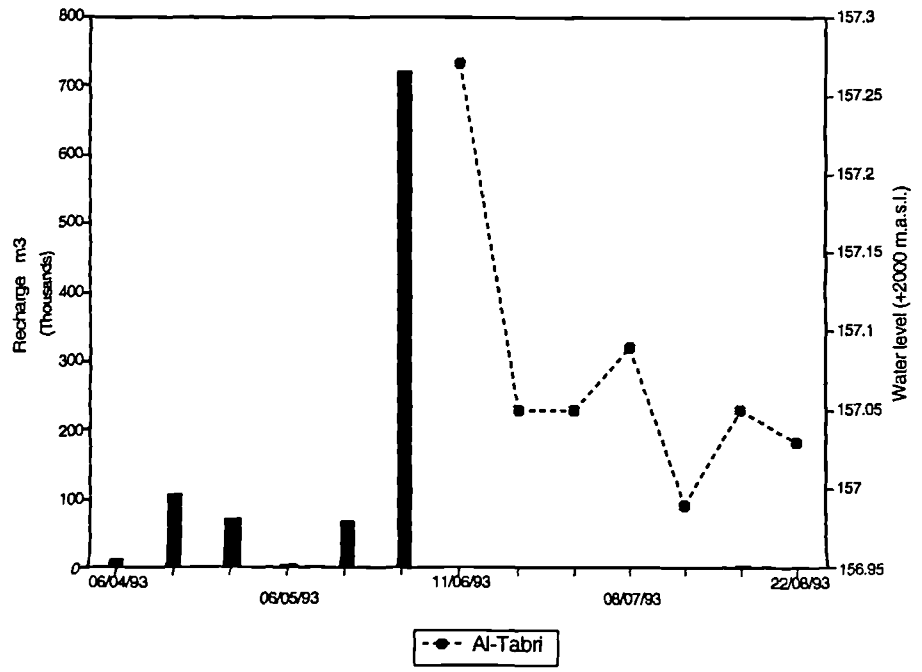


Figure 9.7 Wadi Rujam hydrographs

The general trend of water table fluctuation observed in wells in the wadis is that the maximum rise occurs in May/June and August/September with the minimum levels during October and March.

Within the urban area, measurements were taken from shallow wells and deep boreholes. Regardless to the type of well, the location of the well or borehole and the depth of water table are the main factors determining the response to the first rainy season during 1993. Altabri dug-well, with water table depth of about 45 m and located close to wadi alSyla (Figure 9.8a), shows a delay in response to the recharge events. The time gap between the two rises is similar to the time difference between two recharge events and indicates a lag time of 2 months. Three rises can also be seen in the hydrograph of Alhamadi borehole (Figure 9.8b). The water table in Albaldia borehole (Figure 9.14) starts to rise in 11/6/93 and this continues until 14/8/93. The water table then starts to decline by 0.61 m. Two measurements in July 1991 and May 1995 are available for this borehole and these are described later. Similar readings are available for observation boreholes "ST3" and "A". The hydrograph of "ST3" (Figure 9.8c), shows a rise during the first half of June by 0.16 m. A second rise occurred between 21/7/93 and 6/8/93 but only of 0.05 m. This borehole is not close to Wadi alSyla and the water table is about 60 m from the surface. Two boreholes located away from wadi alSyla at the border of the city, with considerably deeper water table of more than 100 m, show no response to the first rainy season. These are borehole "A" and Alsalam (Figure 9.8d).

(a)



(b)

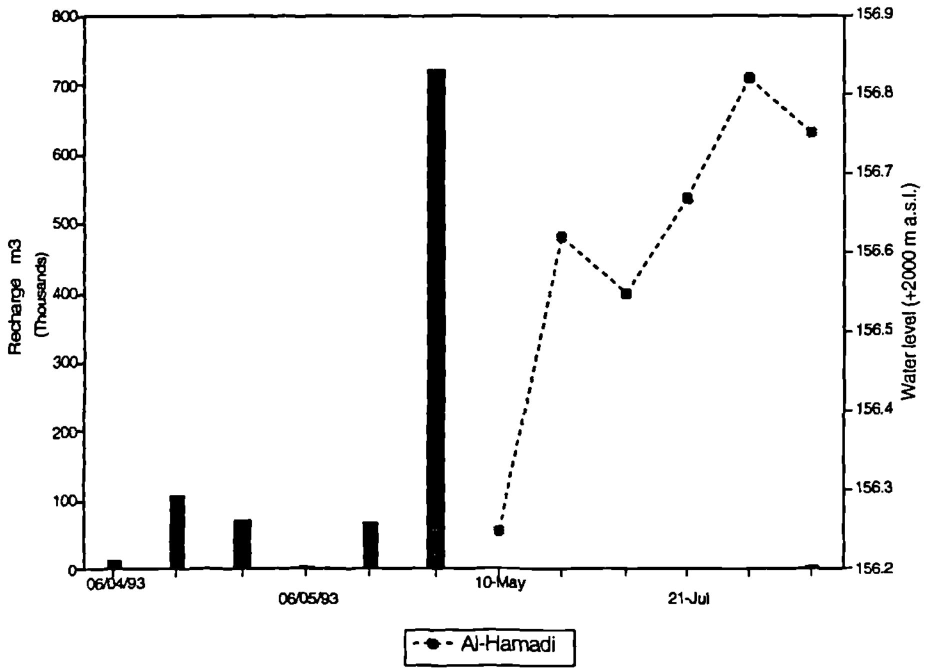
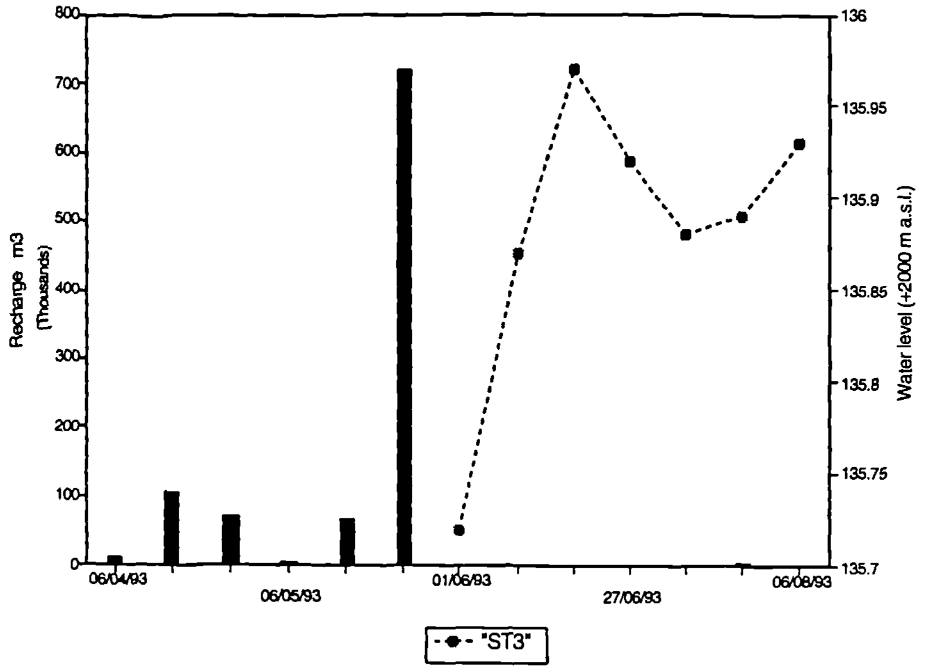


Figure 9.8 Hydrographs of wells within the city a and b.

(c)



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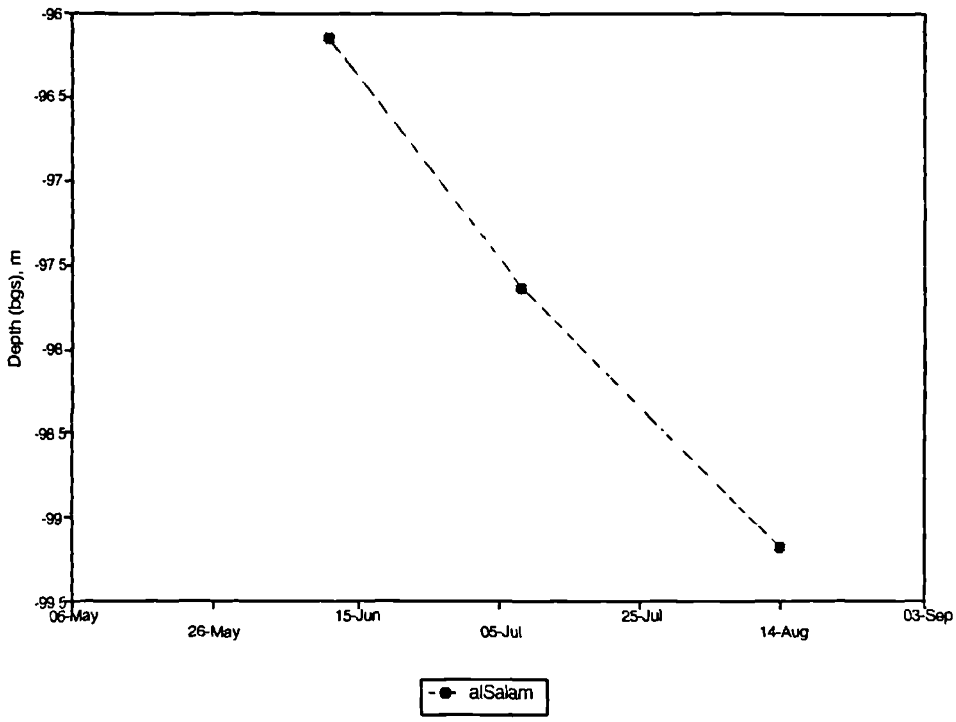


Figure 9.8 Hydrographs of wells within the city c and d.

The wells located north of Sana'a city, respond to recharge events during the first rainy season. The maximum rise shown in Gohiam well (Figure 9.9a), which is located north of Sana'a airport near to wadi alSyla channel, showed a continuous rise of 0.87 m. Mansour well which is located in AlRawdha showed a rise of about 0.22 m between 25/5/93 and 27/6/93, and a similar response is also shown in the water table measured on Algadri well which is located near to Sana'a airport (Figure 9.9b).

Water level fluctuations for NWSA's three monitored boreholes were compared individually with recharge events. These are "EX4", "SE4" and "SE6".

Data from borehole **"EX4"** which taps the Cretaceous Sandstone in the eastern wellfield is available from 21/5/78 to 21/7/91, with a gap between 20/5/80 and 30/3/87. The earlier period before the eastern well field came into operation was compared with the sequence of wadi recharge over eastern part of the basin and is shown graphically in Figure 9.10. The following points were drawn and can be traced in the figure.

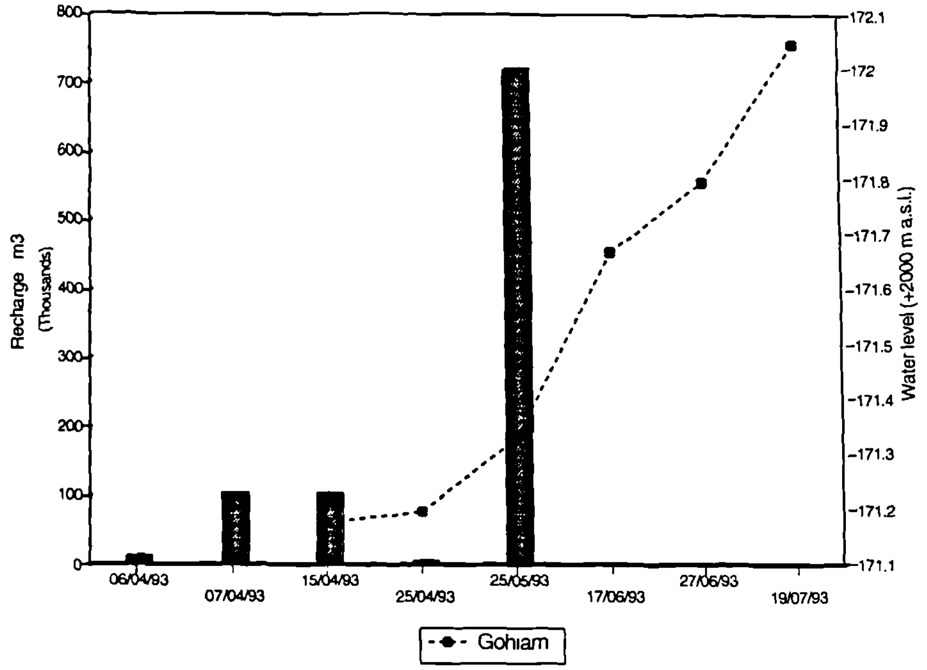
-Delay of about two months between the recharge and the response of the water table.

-Rise of water table during winter months of 1978 was higher than the rise during the end of 1979. The recharge during 1978 was high and no recharge occurred in 1979 over region C.

- Two rises of water level could not be related to recharge events which occurred over eastern wadis, however, their timing agrees with recharge events which took place in western part of the basin.

- For the period between 1987 and 1991, the delay in response of level is longer than two months, 3 months, which may be ascribed to the increase of the depth of the water table by about 30 m.

(a)



(b)

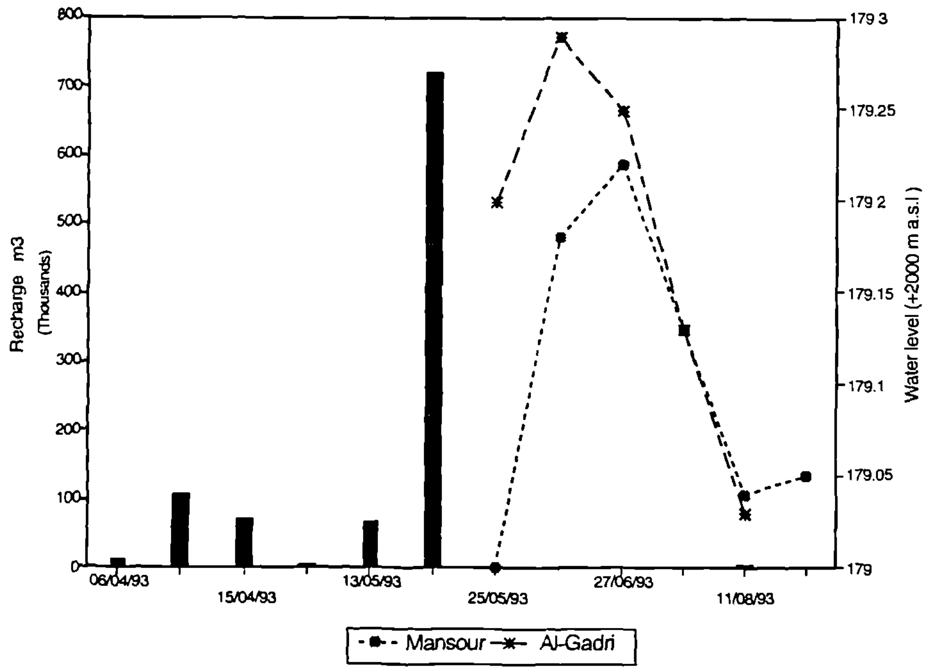


Figure 9.9 Hydrographs over north of the plain a, b

However, the magnitude of the rises and declines of water table during this period were magnified, which might indicate interference from nearby pumping or a change in aquifer conditions.

"**SE4**" taps the Quaternary aquifer and is located in the south of the city near to Wadi Alsyla channel. Water level data between 14/11/76 to 27/7/85 and recharge events over part of southern wadis are shown in figure 9.11. The following conclusions have been drawn;

- A delay of about two months between recharge and response of water level can be traced.
- 1977 was a wet year with maximum recharge. The recharge events were distributed between the two rainy seasons. The rise of water table during June 1977 reflects the response of recharge during the first rainy season. The response for second rainy season is probably combined with the recharge from first season, resulting in a water table rise starting from August 1977 and continuing until May 1978, with the support of two small recharge events in 1/3/78 and 30/4/78. Without the recharge from 1977, these two events might have had no effect in the water table.
- The lack of recovery in 1981 might have been a result of low recharge during 1979 and 1980.

Water level fluctuations for observation well "**SE6**" in the western wellfield at the lower reaches of Wadi Hamdan are available between 1975 to 1988. The period between 1975 and 1978 was compared with recharge through Wadi Hamdan. (The later period excluded because of the change in trend during 1979 when the water level declined by about 20 m (also other boreholes SE1, SE9 and O11), which can perhaps be ascribed to the increased abstraction associated with the start up of more production wells during that period.

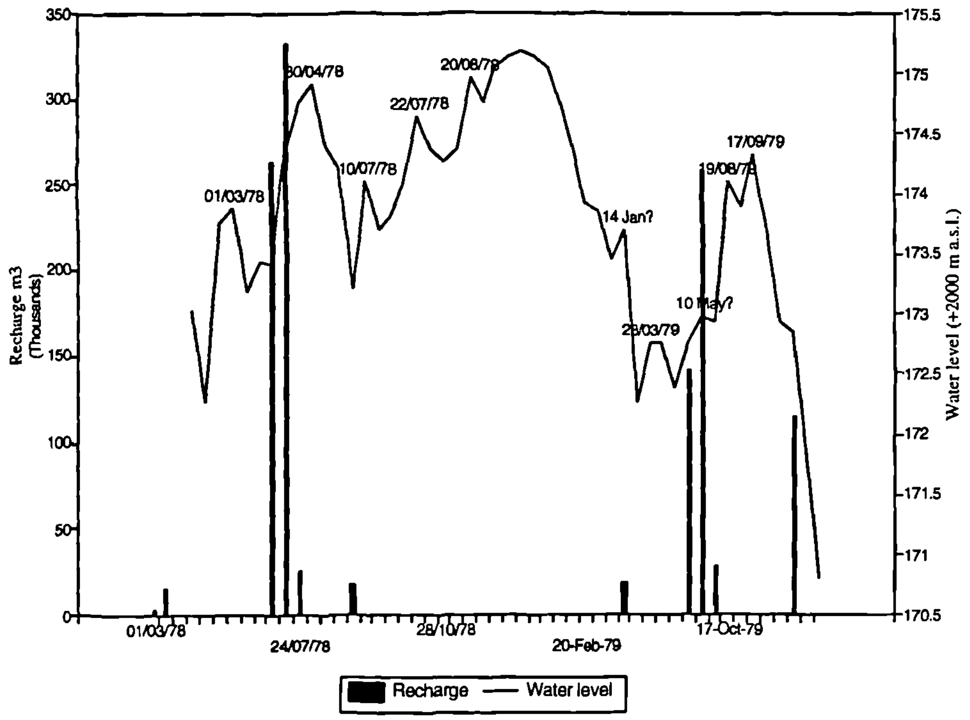


Figure 9.10 Hydrograph of borehole "EX4"

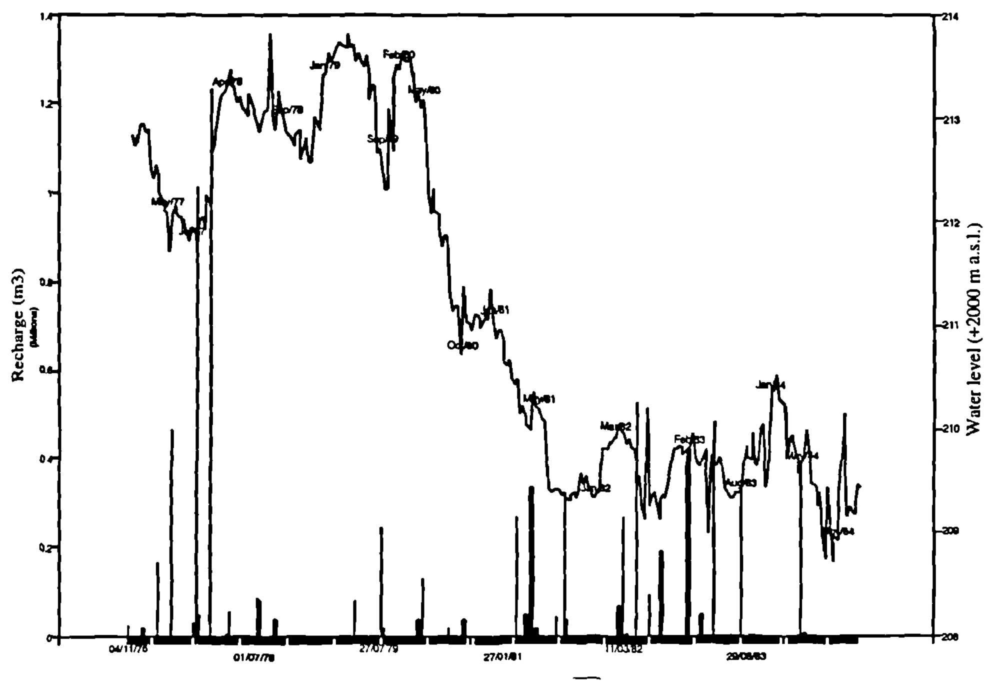


Figure 9.11 Hydrograph of borehole "SE4"

Moreover, abstraction for a bottled water factory near borehole "SE6" probably also has affected readings of water level fluctuation during the subsequent period. The following conclusions have been drawn;

- The rise of the water table during winter months is not due to stopping of abstraction for irrigation alone, but more related to the magnitude of the recharge during the second rainy season. In 1975, (Figure 9.12) recharge occurred in March/April and July/August with almost equal magnitude. This led to a rise during the winter months (late 1975/ early 1976). During 1976, as the recharge was concentrated during first season, no rise was observed during winter months (December 76 and January 77). In 1977, more recharge occurred during the second rainy season (August and October) than the first season, and so a good rise in the water table during the winter months was observed, which lasted until May 1978. This conclusion is supported by the rise of water table during 1975 and 1977 by 1.85 m and 1.84 m, respectively. In contrast, the water table during 1976 declined by 1.57 m.
- An immediate response at the water table can be seen following a runoff event. Still for the wet season, (1975 and 1977) the water level continues to recover over longer period, which probably depends on the magnitude of recharge. The rapid response, however, seems to be masked by the abstraction and the irregular time interval of the readings. This can be explained by the known major feature of infiltration into wadi bed deposits that consist of nonhomogeneous, stratified material. Only a portion of streamflow loss can reach the water table immediately following a runoff event. The rest slowly drains to the water table from the vadose zone over a period of months (WRRC, 1980).

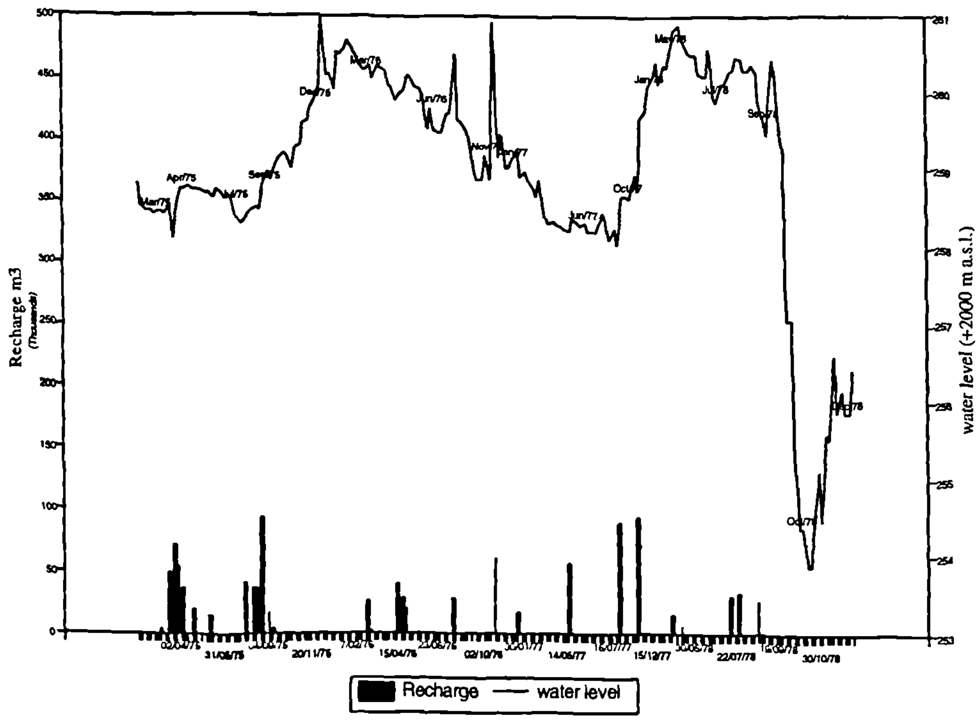


Figure 9.12 Hydrograph of borehole "SE6"

The recharge events occur in two distinct season March/May and August/September, which can be traced in well hydrographs. However, the magnitude of change and the delay time are controlled by the location of the well with respect to the recharge/discharge sources and the type of unsaturated zone material.

The general trend is abstraction in the exploitation zone of the aquifers during the growing season which refers to the stored water extracted between March and September. During winter months when abstraction decreases, if groundwater obtains a large amount of recharge, the cone of depression narrows and the water table rises.

As only annual abstraction from wellfield area is available, this limited the attempt to analyse the annual difference between recharge and abstraction compared with the groundwater level fluctuations. The effect on the water table of abstraction is faster, but there is a delay time for the water table to respond to recharge. The situation is clearer for the urban area and is discussed below.

In general, the long term trend of water level in the wellfield area can be presented by hydrograph of borehole "H", Figure 9.13. Although the general decline of the water table may be related to the accelerated increase of groundwater abstraction (see figure 9.4a), decline in the annual recharge volume since the mid 1980s can been seen in Figure 9.13.

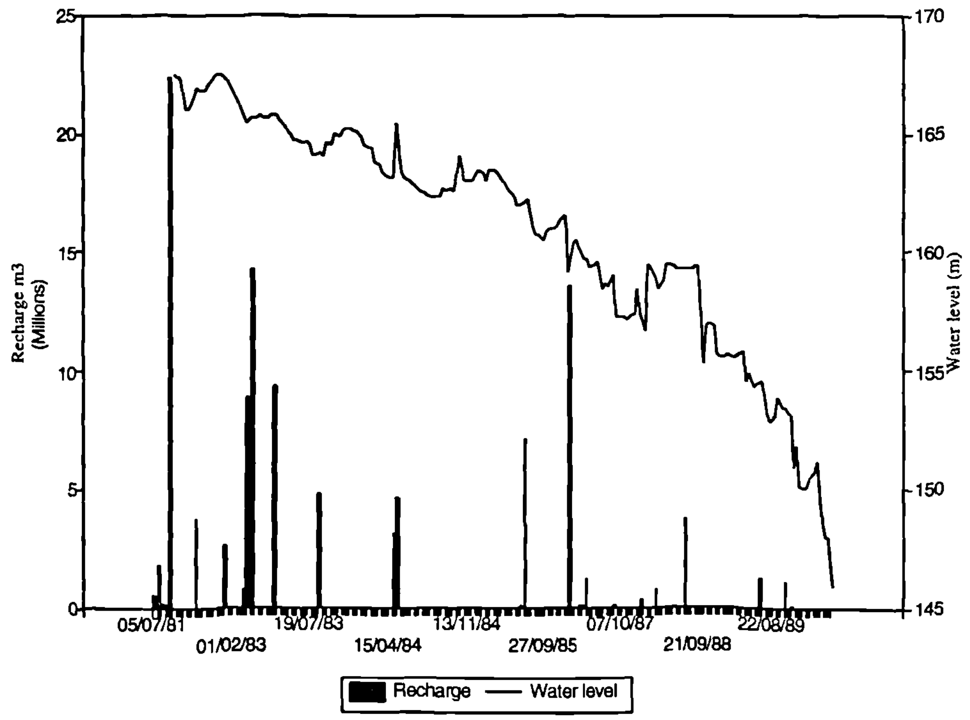


Figure 9.13 Hydrograph of borehole "H"

9.5.3 Urban recharge-abstraction and water level

The urban area is controlled by both abstraction from private wells and boreholes and urban man-induced infiltration. In 1972, Italconsult (1973) reported a declining groundwater level when the abstraction was estimated as 4.5 MCM and inflow as 2.5 MCM. This condition changed during 1980, with the expansion of the water mains within the city and absence of sewerage system. Even when the sewer system started in 1986, it covered only part of the city. Mosgiprovodkhoz (1986) reported a steady state condition over the city, as indicated from the stable water table observed in borehole 5P during 1983 to 1985. Two additional measurements in July 1991 and May 1995, beside the regular measurements during 1993, from borehole Albaldia within the city are illustrated in Figure 9.14.

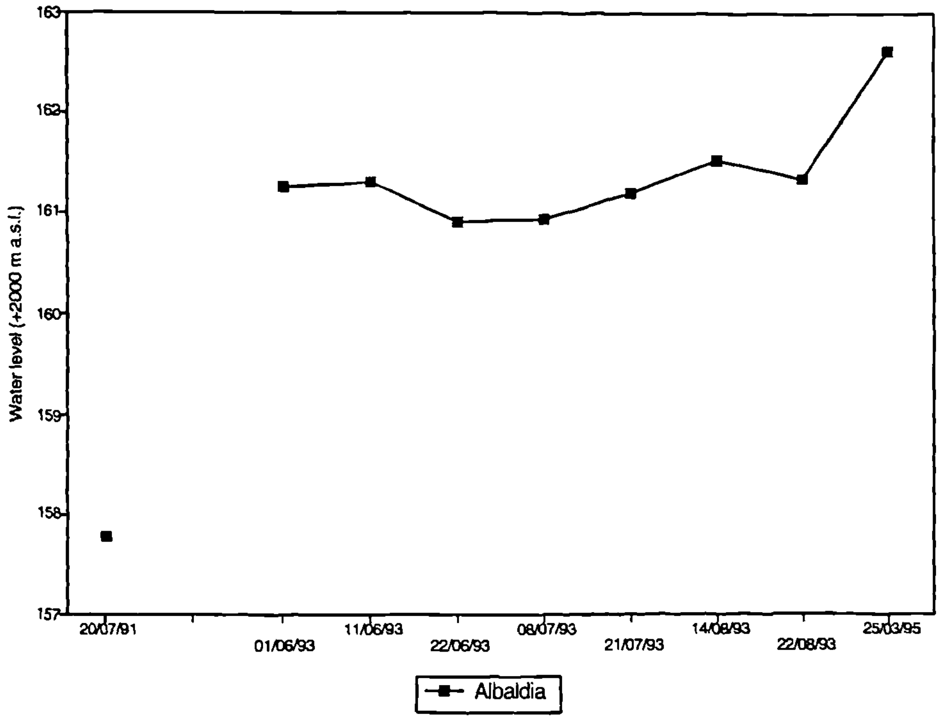


Figure 9.14 Hydrographs of Albaldia borehole.

The Figure indicates rise of water table by 1.27 m between June 1993 and March 1995. The rise between July 1991 and July 1993 was 3.48 m.

Fluctuations of the water level in the urban area agree with the results obtained from the recharge-abstraction analysis. The annual difference between urban abstraction and urban recharge over the urban area between 1974 and 1993 is shown in Figure 9.15 together with its cumulative.

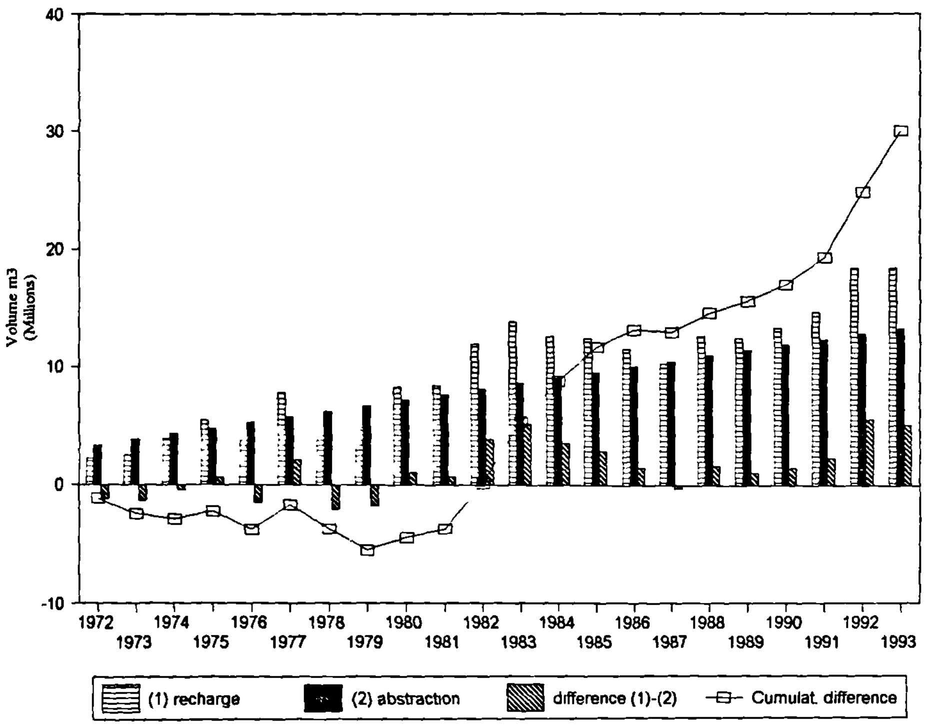


Figure 9.15 Annual difference and the cumulative between urban recharge and abstraction.

10 Conclusions and recommendations

The tectonic and volcanic activity has affected the surface and the subsurface conditions of the basin and consequently all components of the water cycle. The dissection of the terrain by faults and volcanic intrusions caused difficulties in obtaining accurate physical characteristics of the aquifer systems.

The up to date groundwater abstraction and use show a continuous increase in all water sectors. A steep increase in groundwater abstraction for irrigation started in 1986/1987 when the government abandoned import of vegetables and fruits, and consequently there was a shift to cash crops and irrigation.

The average annual rainfall (1974-1993) over the basin is 224 mm. The annual time series (1938-1993) show a greater degree of random inter-annual fluctuation, and a secular trend of a decrease in the annual rainfall by 3.45 mm annually has been calculated. Moreover, the long term component indicates a change in the mid 1960s from an increasing to a decreasing average rainfall. In general, this was accompanied by a change in the seasonal trend of the rainfall. The contribution of second rainfall season in the amount of the annual rainfall is less during recent years than it was during wet years.

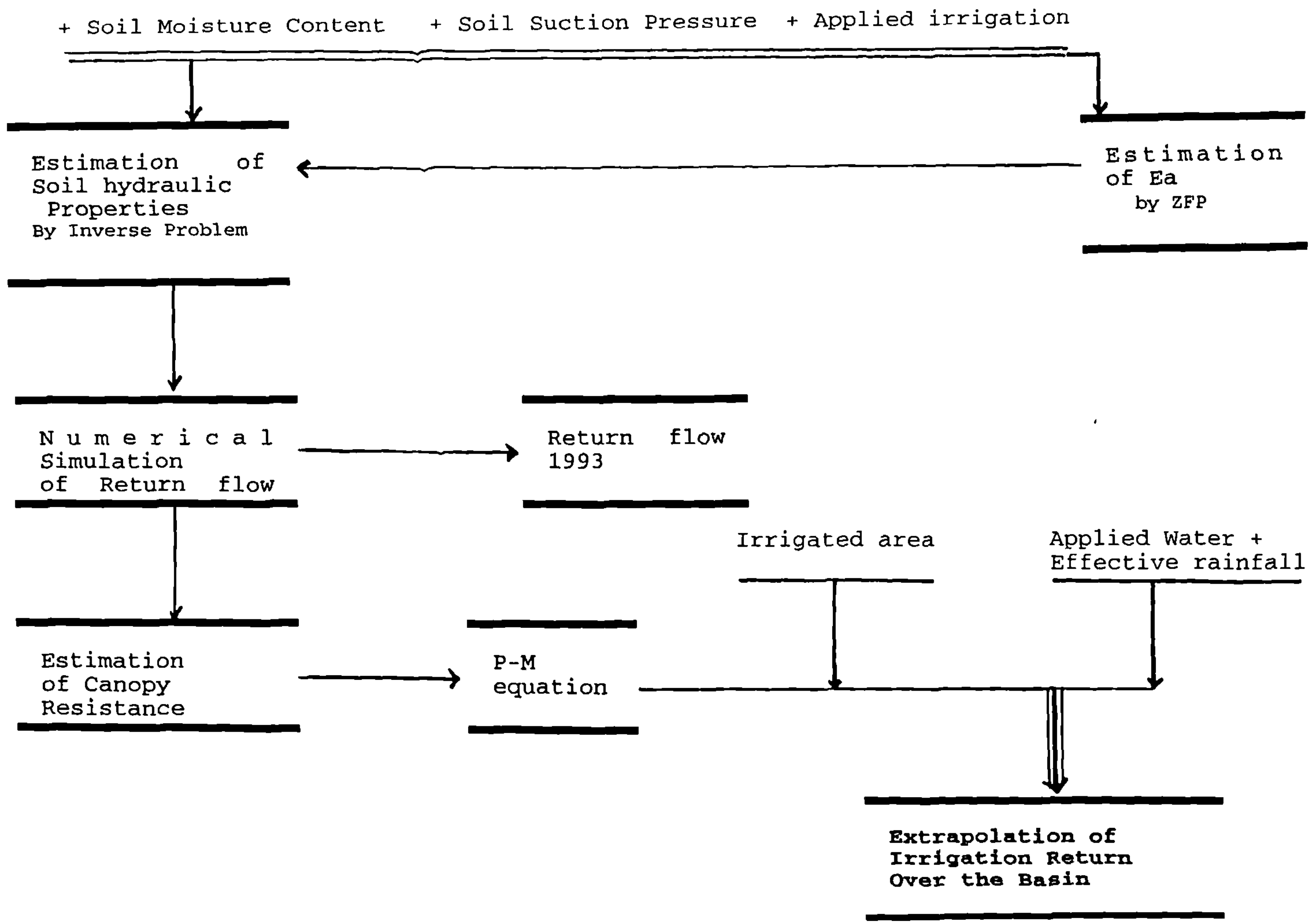
The climatological conditions for groundwater recharge make direct recharge insignificant process and groundwater recharge takes place through wadi bottom and under irrigated fields.

With a careful procedure in the field and under favourable conditions (i.e measurable soil moisture and soil suction pressure), reliable values of the local evapotranspiration can be obtained from regular measurements of soil moisture content and soil suction pressure along the soil profile. The measured actual evapotranspiration can then be used to evaluate the canopy resistance (rc), and so overcome the main drawback of the Penman-Monteith equation, which proves to be very sensitive to this parameter, when the actual evapotranspiration is to be estimated from meteorological data.

With reasonable accuracy, soil hydraulic properties have been estimated for three sites by solving the flow problem using a computer program for one-dimensional vertical flow. An initial value of the suitable soil hydraulic fuction for each site was estimated from a computer program (SOIL), which uses a non-linear, least squares analysis to estimate the curve shape paramters for the four most common analytical expression for soil hydraulic functions, using measured soil moisture content and soil suction pressure. Credible estimates of irrigation return for the main irrigated crops in the Sana'a basin were obtained, and the rates of the return flow are based on modelling of unsaturated flow calibrated against field measurements of soil moisture and suction pressure. This leads to more realistic and reliable values of return flow, which can be applied widely, provided that the measurement sites are representative of the whole study area. The percentage of the applied irrigation water that returns is 25% for grapes, 30% for qat and 49 % for apples.

The total overall return flow over the basin during 1993 was estimated as 47.6 MCM. Temporal regionalization by a water balance approach over a period of 8 years (1986-1993) shows the return flow varies between 16.3

Methodology sequence of irrigation recharge estimates



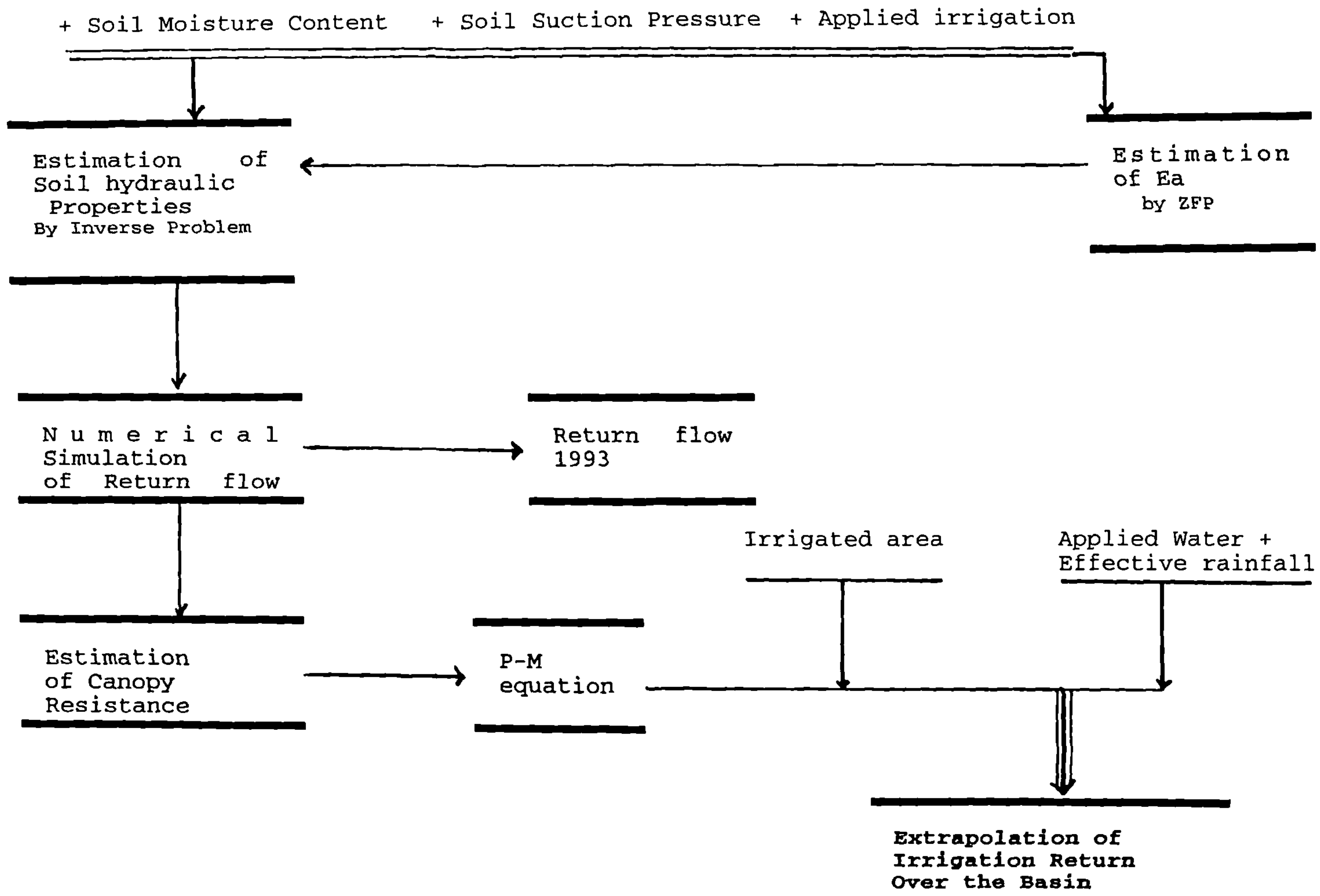
MCM in 1991 to 61.5 MCM in 1992, with an average of 30 MCM/year. Obtaining similar average figures by using percentage of groundwater abstraction alone for the same period allow the annual irrigation return to be extended back to 1974.

The approach demonstrates and emphasises that the required accuracy of soil hydraulic properties depends upon their application. The only disadvantage of the technique is that collection the field data is time consuming. However, the data were useful for other applications, including the rainfall-runoff model, rates of direct recharge from rainfall alone and determination of actual evapotranspiration.

The rainfall-runoff model was used to estimate wadi flows over a 20 year period from 16 ungauged wadis in the Sana'a Basin. The annual flows vary from one wadi to another depending largely upon the rainfall and catchment topography and geology. Subsequent application of a regression equation allowed estimation of recharge to the alluvium in the catchments where the available data comprise only topographic and soil maps and daily rainfall data. The indirect recharge over the basin varies between 147 MCM in 1977 to 3 MCM in 1991 with an annual average of 38 MCM/year.

The combination of the rainfall-runoff and channel water balance models provides a powerful tool for the estimation of recharge from ephemeral wadis when data are scarce. The independent verification of both calculations using measured flows and observation well hydrographs confirms the suitability of this approach for the conditions in the Sana'a basin and other arid areas.

Methodology sequence of irrigation recharge estimates



Estimation of groundwater recharge from ephemeral wadis by calibration of a groundwater model can give useful results, even for areas such as the Sana'a basin where there are few measurements of floods. A valid estimate of groundwater recharge can be obtained without a complete representation of the unsaturated zone. Although the developed model may be used predictively to compute recharge over longer period of time, due to the limitations of the Streamflow package in MODFLOW, it was used to provide an independent check on the simple channel water balance method estimates, and allowed sensitivity analysis of recharge to some of the flow characteristics parameters. It showed that the magnitude of the cumulative infiltration through the wadi beds is largely dependent on the duration of the flood, but that flood discharge and the distribution of flood intensity have only minor influence.

The method requires an extensive set of subsurface data to allow successful calibration of the intial steady state model, which forms the basis for the subsequent transient phase. The essential items for transient calibration are measured or calculated floods and groundwater hydrographs, spanning both the recovery during the rainy season and the recession during the following dry season. A unique calibration would be impossible without use of the falling limb of the hydrographs to estimate the specific yield of the aquifer. The presence of a distinct rainy season, or a series of separate floods is therefore essential.

The time required for implementation of this approach depends on the number of floods, as each must be simulated individually. Due to the amount of work involved and the requirements for extensive subsurface data, this approach is not suitable in all cases. In addition, the limitations and assumptions of MODFLOW's streamflow-routing package may become significant, for example in areas with a very deep water table.

An accurate urban recharge figure was estimated using the recently collected data for abstraction, which allows reliable figures to be put on the unmeasured components of urban water balance. The annual urban recharge varies between 2.3 MCM in 1974 to 17.4 MCM in 1992 with annual average of 10.5 MCM. The major contributor (58%) is the return flow through cess-pits. The increase of mains network coverage during the 1980s, and the consequent increase of the flow to cess-pits, leads to a rise of water level under the city, instead of the declining trend observed during 1970s.

Although in general the Cretaceous sandstone aquifer does not show any signs of progressive deterioration of water quality due to over exploitation or pollution from unsuitable land use in the recharge zone, local contamination from the polluted part of the shallow aquifer to the Sandstone is evident.

Water salinity in the Cretaceous sandstone varies between 500 mg/l to about 1000 mg/l, the highest is related to old confined water and/or low permeability zones controlled by geological structure. The salinity of the volcanic aquifer is lower, less than 600 mg/l, and reflects insoluble aquifer material as well as sufficient dilution of the irrigation return flow.

Contamination of the shallow aquifer in lower reaches of primary wadis as a result of irrigation return is evident. However, the total dissolved solids of less than 1000 mg/l indicates that sufficient dilution is occurring when it mixes with wadi recharge as well as the deeper aquifer water. Moreover as the use of fertilizer is not common, this reduces risk to downstream users.

A similar situation exists over most of Sana'a city and the northern part of the plain, however, with an additional risk of biological contamination.

Analysis of recharge and abstraction over a period of 20 years (1974-1993) indicates out that, of the 11 hydrogeological zones, only 4 hydrogeological zones, Dhar, Hamdan, Hizyz and AlMhajir have groundwater recharge in excess of the abstraction. The severity of mining in the other 7 hydrogeological zones, however, varies between one zone and another. The decline of groundwater level in the wellfield area is a combined result of declining of recharge rates, excessive abstraction, and changes in aquifer conditions.

Recommendations

Any further enhancing for the recharge values could be done only by additional data collection and monitoring. The monitoring programme should include regular measurements of:
wadi flow at some wadis (e.g. Alsir, Dhar, Gyman, Akhwar);
private abstraction for irrigation, at least for a sample of farms;
continuous records of groundwater levels away from the wellfield area, for both shallow and deep aquifers;
water quality for both shallow and deep aquifers, with special emphasis on boreholes within the city.
The collected data would allow new methods of recharge estimation to be tested as well as improvement in the evaluation of the available resource.

Further additional work should include:

Interpretation of the stable isotope analyses, when they become available, for samples collected during the present study;

Estimation of the inter-aquifer recharge component using both piezometric data from the aquifers and hydrochemical data;

Annual updating of recharge estimates.

An attempt to incorporate hydrological and hydrochemical information into a mathematical groundwater model of solute transport in the aquifer, which might be coupled with optimization techniques, would be required for a proper quantification of the effect of the recharge components in the groundwater quality. Until then, however, it is believed that the use of cess-pits within the city provides a better chance for natural filtration of the domestic waste water than the existing system which collects, transfers, and discharges waste water into the wadi channel with the surface flows.

The new gained information from the present study should be incorporated into the water planning for Sana'a through revision of management strategies and development of groundwater management policy for the Sana'a basin.

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APPENDICES

Appendix A

(A-1 TO A-76)

Hydrometeorological data

AIPORT Rainfall mm	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
1.1	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.1	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.1	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
16.1	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0
17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
19.1	0	0.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.1	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.1	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	7.8	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0
9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.2	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	3.5	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
13.2	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.2	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0
16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.2	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.2	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0
21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.0	0.0	0.0	0.0	0.0
22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.2	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	1.0	0.0	0.0
25.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0
26.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0	0.0
27.2	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0
28.2	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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1.3	0.0	0.0	1.1	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
2.3	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	4.2	0.0	0.0	0.0
3.3	0.0	0.0	12.2	0.0	0.0	0.0	0.0	0.0	14.6	0.0	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	41.2	0.6	0.0	0.0	0.0	0.5	0.0	0.0
8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	32.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0
9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.3	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
12.3	0.0	0.0	0.0	0.0	1.8	6.5	0.0	0.0	0.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	10.0	0.0	0.0
17.3	0.0	0.0	0.5	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.8	0.0	0.0
18.3	0.0	0.0	0.0	0.6	0.0	0.0	0.0	13.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.3	0	1.4	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.3	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.2	0.0	0.0	0.0	3.8	0.0
21.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.3	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	15.0	0.0
23.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
24.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
25.3	0.0	0.0	0.0	0.0	0.0	0.0	4.6	1.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
26.3	0.0	0.8	9.7	0.0	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.3	0.0	0.6	2.2	0.0	0.0	0.0	11.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	7.0	0.0	0.0	0.9
28.3	0.0	20.0	0.0	18.4	0.0	15.0	0.0	8.7	0.0	9.9	1.3	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.5
29.3	0.0	0.0	0.0	1.0	0.0	0.0	0.0	13.7	23.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	3.0
30.3	0.0	6.0	2.2	0.0	0.0	0.0	0.0	1.3	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	2.1	0.0	8.0
31.3	0.0	15.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	6.2	0.0
1.4	0.1	12.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	1.6	0.0	0.0
2.4	16.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.0	1.3
3.4	7.8	10.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	1.0	0.0	0.0	12.7	0.0	0.0	0.0
4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	0.0	0.0	0.0	1.5	0.0	0.0	8.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.7	0.0	6.3	0.0	0.0	0.0	11.2
7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	0.8	1.6	1.8	0.0	9.9	0.0	0.0	0.0	16.4
8.4	14.2	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.5	1.0	0.0	12.9	0.0	0.0	0.0	0.0
9.4	0.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.3	5.7	0.0	13.4	0.0	0.0	0.0	0.0
10.4	90.0	0.5	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	5.8	1.4	0.0	1.0	0.0	0.0	0.0	0.2
11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4
12.4	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	4.3	13.0	1.6	0.0	2.0	0.0	0.0	0.0	0.0	1.4
13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.6	0.0	0.8	0.6	0.2	0.0	0.0	0.0	0.0	4.6
14.4	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	5.1	0.0	19.0	0.0	0.0	0.0	0.0	7.2
15.4	0.0	0.8	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.3	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	15.2
16.4	0.0	0.6	0.0	0.0	3.2	0.0	15.5	0.0	0.0	0.0	0.0	0.0	8.4	0.0	14.0	0.0	0.0	0.0	0.0	0.7
17.4	0.0	0.0	0.0	0.0	3.2	0.0	13.1	0.0	0.0	0.0	0.0	0.0	1.7	0.0	8.4	0.0	0.0	0.0	0.0	4.5
18.4	0.0	3.4	0.0	0.0	0.0	0.0	12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0
19.4	0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	6.0	0.0	0.0	0.0	0.0	0.4
20.4	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
21.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	15.7	17.2	0.0	6.3	0.0	0.0	0.0	0.0	0.0
22.4	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0	3.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0
23.4	0.0	1.8	7.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2	0.0	0.0	0.3	0.0	8.7	0.0	10.0	0.0	0.0	0.0
24.4	0.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	9.0	3.5	0.0	0.0	0.0
25.4	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7	0.0	0.4	7.6	0.0	0.0	8.0	0.0	0.0	0.0	0.2
26.4	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	1.0	0.0	0.0	0.0	4.7	0.0	0.0	10.0	0.0
27.4	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	15.6	0.0	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4
28.4	0.0	0.0	3.5	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0
29.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
30.4	0.0	0.0	0.0	0.0	19.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1.5	0.0	0.0	3.0	0.0	2.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	3.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.5	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4
5.5	0.0	0.0	7.9	1.2	7.0	6.5	0.0	0.0	0.0	0.0	0.0	2.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.5	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	1.2	12.8
7.5	0.0	0.0	0.0	0.0	1.0	6.5	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0
8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1	0.0	7.2	10.4	0.0	1.4	0.0	0.0	0.0	0.1	0.0	0.0
9.5	15.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	11.6	0.0	4.2	4.3	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0
10.5	2.2	0.0	1.2	0.0	0.0	3.3	0.0	0.0	45.1	0.0	10.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	1.1	0.0
11.5	3.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
12.5	52.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5
13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.8
14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.5	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	31.3
15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8
17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.5	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0
19.5	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
20.5	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.5	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	10.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0
23.5	7.6	0.0	0.0	22.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0
24.5	9.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.5	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.5	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0
1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	1.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.0
7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	0.0	0.0	0.0	0.0
9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0
14.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.6	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.6	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
23.6	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.6	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0

1.7	0.0	00	00	00	0.0	06	0.0	0.0	0.0	00	0.0	00	04	0.0	00	0.0	0.0	00	0	00
2.7	0.0	0.0	00	0.0	00	0.0	00	00	0.0	00	0.0	00	0.0	0.0	00	00	00	00	00	00
3.7	0.0	0.0	00	0.0	00	0.0	0.0	00	0.0	00	0.0	00	00	0.0	00	00	00	07	00	00
4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	0.0	00	00	0.0	00	00	00	00	00	0.0
5.7	1.5	0.0	0.0	0.2	0.0	0.0	00	200	0.0	00	0.0	00	04	00	00	00	00	00	00	00
6.7	0.0	0.0	00	00	00	0.0	00	00	00	00	00	00	00	00	00	00	00	00	00	00
7.7	0.0	0.0	0.0	00	0.0	0.0	00	00	00	0.0	00	00	00	00	00	00	0.0	00	00	00
8.7	0.0	0.0	0.0	00	0.0	0.0	00	00	0.0	0.0	0.0	00	00	00	00	0.0	0.0	30	00	00
9.7	0.0	0.0	0.0	00	0.9	0.0	00	00	0.0	00	0.0	0.0	00	00	00	00	00	00	00	00
10.7	0.0	0.0	0.0	0.0	20.8	0.0	0.0	0.0	0.0	00	0.0	00	0.0	00	00	00	00	00	00	0.0
11.7	00	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	00	16	00	00	0.0	00	0.0	00	00	00	0.0
12.7	0.0	0.0	00	0.0	00	0.0	0.0	0.0	00	00	0.0	00	00	0.0	00	0.0	00	00	00	0.0
13.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	0.0	0.0	0.3	0.0	0.0	0.0	00	0.0	00	0.0	0.0	00
14.7	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	00	00	00	00	0.0	0.0	00	0.0	00
15.7	0.0	0.0	0.0	0.0	7.0	0.0	00	0.0	0.0	0.0	0.0	0.0	00	00	60	0.3	0.0	00	00	00
16.7	0.0	0.0	0.1	0.0	65	4.5	00	0.0	00	00	0.1	0.0	0.0	00	08	0.0	0.0	00	00	00
17.7	0.0	0.0	0.0	0.0	00	0.0	00	0.0	00	00	1.5	0.0	2.4	00	00	0.0	00	00	00	00
18.7	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	00	0.0	0.0	00	0.0	00	87	0.0	00	00	00	0.0
19.7	0	0.0	0.0	0.0	3.3	0.0	0.0	0.8	00	0.0	0.0	96	20	00	00	0.0	00	00	00	0.0
20.7	0.0	00	0.0	0.0	0.0	0.0	0.0	0.0	00	0.0	0.0	0.0	00	00	320	00	00	00	13	0.0
21.7	00	00	2.4	0.0	0.0	0.0	0.0	0.0	0.0	08	0.9	00	13	00	28	00	00	00	05	05
22.7	0.0	00	14.5	0.0	200	00	00	00	00	00	00	00	00	00	00	65	17	00	00	00
23.7	00	00	00	0.3	37	00	00	00	00	00	00	00	10	00	00	00	46	00	00	00
24.7	0.0	00	0.0	0.4	00	1.9	00	00	0.0	00	0.0	00	00	00	00	00	23	00	00	07
25.7	0.0	00	0.0	0.0	0.5	0.8	0.0	0.0	00	00	0.0	0.0	0.0	00	11.6	00	8.4	00	00	0.0
26.7	0.0	24.5	0.0	0.0	0.0	0.2	0.0	00	0.0	00	0.0	00	00	00	05	00	10.6	00	00	0.0
27.7	0.0	25.0	0.0	0.0	09	00	0.0	0.0	00	0.0	00	00	8.7	00	00	0.0	00	00	00	0.0
28.7	0.0	15.0	0.0	0.0	0.0	08	0.0	0.0	00	00	0.0	00	10.5	00	12	0.0	00	00	158	00
29.7	0.0	20.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	00	0.2	0.0	18	00	7.3	00	00	02	00	00
30.7	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	00	0.0	0.0	1.8	00	23	0.0	40	00	00	00
31.7	0.0	0.9	1.5	190	1.2	0.0	00	0.0	0.0	00	0.0	00	16	00	00	00	46	00	136	0
1.8	0.0	0.0	0.0	0.0	0.0	00	0.0	29.5	0.0	00	00	00	58	00	00	26	00	00	00	00
2.8	0.0	0.0	0.0	00	00	0.0	00	10	0.0	00	00	00	00	0.0	00	00	00	00	00	00
3.8	2.5	0.8	0.0	0.0	0.0	0.0	0.1	0.0	0.4	00	0.0	00	00	00	30	07	00	00	00	00
4.8	3.2	1.0	0.0	0.0	0.2	0.0	0.1	2.0	05	00	00	00	00	05	00	06	00	00	06	00
5.8	4.0	0.0	0.0	0.0	0.0	0.0	01	4.8	0.0	00	0.0	00	00	02	03	00	00	00	00	00
6.8	18.4	0.0	0.0	0.2	00	0.0	00	0.0	0.9	00	00	00	00	5.2	00	00	24	00	00	00
7.8	0.0	10.1	0.0	0.7	0.0	0.0	1.6	00	0.0	00	00	00	00	08	00	23	00	00	00	00
8.8	9.0	2.0	0.0	0.0	0.0	0.0	0.3	00	120	00	00	00	00	00	00	00	00	00	0.1	120
9.8	0.0	1.0	0.0	0.0	00	0.0	00	00	00	00	00	00	00	00	00	00	00	01	01	9.4
10.8	0.0	10.0	0.8	0.0	00	0.0	0.4	00	00	00	00	00	08	67	00	08	00	26	148	00
11.8	0.0	4.0	0.3	0.0	4.9	0.0	4.0	0.0	0.0	00	00	00	00	38	00	00	00	00	163	00
12.8	1.0	3.0	0.0	5.4	01	0.0	26	00	00	00	01	00	00	14	10	00	00	00	93	00
13.8	1.5	00	2.6	5.8	00	0.0	87	00	00	158	76	00	00	17	00	00	00	73	60	00
14.8	6.0	00	0.0	7.7	0.0	97	07	50	00	62	10	00	00	00	00	02	00	32	91	05
15.8	0.0	3.9	0.0	300	00	00	11	0.0	00	100	00	00	00	00	00	00	00	00	09	00
16.8	0.0	11.0	00	25.5	00	00	1.5	7.7	00	249	00	00	5.5	00	37	00	00	00	02	00
17.8	0.0	04	00	0.1	10	0.5	20	00	00	10	00	00	219	00	02	00	43	00	40	00
18.8	0.0	00	0.0	51	00	0.8	00	20	00	00	00	00	2.2	00	06	35	00	00	00	00
19.8	0	0.5	00	00	0.0	27	01	250	00	00	00	00	11	00	04	00	00	00	00	00
20.8	0.0	0.3	0.0	0.0	105	00	00	23	00	00	00	00	00	00	00	00	00	00	00	00
21.8	0.0	89	0.0	07	00	48	00	06	00	35	00	00	00	04	00	04	00	00	00	00
22.8	0.0	28.4	00	00	00	00	00	00	00	00	00	00	00	06	00	13	00	00	171	00
23.8	0.2	2.0	00	00	00	0.0	00	00	00	00	00	00	00	00	00	00	00	00	43	00
24.8	0.0	7.0	00	00	00	00	00	00	00	00	00	00	00	00	02	00	00	00	19	00
25.8	0.0	17	00	00	00	0.0	00	00	00	00	00	00	00	00	10	00	00	00	11	00
26.8	0.0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	10	00
27.8	0.0	00	00	00	00	14	00	00	00	00	00	00	00	00	00	00	00	00	00	00
28.8	0.0	0.0	00	00	00	00	00	00	17	00	00	00	00	00	00	38	00	00	00	00
29.8	0.0	00	0.0	00	00	00	2.7	00	2.0	00	00	00	00	00	00	00	00	01	00	00
30.8	0.0	0.0	00	00	00	0.0	1.7	00	00	00	00	00	00	00	27	00	00	00	00	00
31.8	0.0	0.0	0.0	00	00	0.0	00	00	00	00	00	00	00	00	76	00	0	00	00	00

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1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.2	0.0	1.4	0.0	0.8	0.0
6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.7	0.0
7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	0.0	0.0	0.0	0.0	0.0
8.9	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0
11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0
18.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.9	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0
1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.7	0.0
10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.1	0.0	0.0	0.0	0.0	0.0	0.0	36.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.1	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.1	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.1	0.0	0.0	0.0	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.1	0.0	0.0	0.0	29.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.1	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.1	0.0	0.0	0.0	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.1	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.1	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.1	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.1	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A-5

1.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.11	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.11	0.0	0.0	26.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.11	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.11	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.11	0.0	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.11	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.12	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.12	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.12	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
6.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
11.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.12	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0
20.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.12	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
31.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0
			0.0				0.0				0.0				0.0				0.0	

A-6

Daba'at Rainfall mm	74	75	76	77	78	79	1980	81	82	83	84	1985	86	1987	88	1989	1990	91	92	93
1.1	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.1	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.1	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
16.1	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0
17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
19.1	0.0	0.0	0.0	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
24.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.1	0.0	0.0	0.0	0.0	0.0	5.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.1	0.0	1.3	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.1	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.1	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
7.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0
8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	0.0	0.0	0.0
9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	1.8	0.2	0.0	0.0	0.0
11.2	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	3.2	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
13.2	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.2	0.0	0.0	0.0	0.0	2.6	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0
16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.2	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0	0.0
21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.1	0.0	0.0	0.0	0.0	0.0
22.2	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.2	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.2	0.0	0.0	1.6	0.0	0.0	0.0	0.0	16.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.9	0.0	0.0
26.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0
27.2	0.0	0.0	2.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0
28.2	0.0	0.0	0.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	5.5	0.0	0.0	0.0	0.0	0.0

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1.3	0.0	00	00	0.0	159	0.0	0.0	00	0.0	0.0	00	0.0	0.0	12.2	00	00	00	00	00	00
2.3	00	0.0	3.0	0.0	0.8	0.0	0.0	0.0	0.0	00	00	00	00	00	00	00	107	00	00	0.0
3.3	1.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	22.3	00	00	00	143	00	00	00	0.0	00	00	00
4.3	0.0	0.0	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	269	02	00	00	00	00	00	00
5.3	0.0	0.0	1.4	00	0.0	00	0.0	0.0	32	00	0.0	00	00	00	0.0	0.0	00	00	00	00
6.3	0.0	0.0	00	00	0.0	00	0.0	0.0	00	00	0.0	00	00	54	00	00	38	00	00	00
7.3	2.4	0.0	20	00	0.0	00	0.0	0.0	23	00	00	00	412	42	00	00	00	08	00	00
8.3	02	0.0	00	0.0	0.0	00	0.0	0.0	0.9	19.2	00	00	00	02	00	00	00	104	00	00
9.3	00	00	00	0.0	0.0	0.0	00	00	00	00	00	00	82	02	00	00	00	00	00	00
10.3	0.0	0.0	00	0.0	0.0	0.0	00	0.0	0.0	00	00	00	00	02	00	28	00	00	00	00
11.3	00	0.0	0.0	00	4.0	0.0	0.0	4.8	00	0.0	00	00	00	230	00	00	00	09	00	00
12.3	00	00	00	00	28	100	32	3.1	00	234	00	00	00	76	00	00	00	00	0.0	00
13.3	00	0.0	02	0.0	00	00	1.2	04	03	228	00	0.0	00	0.0	00	00	00	00	0.0	00
14.3	0.0	0.0	02	0.0	0.0	0.0	0.0	38	0.0	42	00	0.0	00	0.0	00	00	00	00	00	00
15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	00	00	0.0	0.0	00	00	00	0.4	00	00	00	00
16.3	00	0.0	0.0	00	0.0	0.0	00	00	0.0	00	0.0	68	00	0.0	00	0.0	00	153	00	00
17.3	0.0	0.0	00	0.0	0.0	0.0	0.2	184	00	00	0.1	00	00	0.2	00	06	00	1.2	00	0.0
18.3	02	0.0	15.2	1.5	0.0	0.0	0.6	19.0	0.0	0.0	7.7	00	0.0	00	00	00	00	00	0.0	00
19.3	66	2.1	00	0.0	0.0	0.0	0.2	4.0	0.0	0.0	09	02	00	18	00	1.0	136	00	00	00
20.3	4.6	10.7	0.0	0.0	0.0	0.0	19.0	0.0	0.0	00	0.0	0.4	4.6	02	05	00	0.2	00	58	00
21.3	8.4	0.0	00	0.0	0.0	00	0.0	0.0	0.0	0.0	00	00	0.0	00	00	00	08	00	00	00
22.3	0.4	0.0	0.0	00	0.0	00	0.0	06	00	00	00	02	00	00	00	02	24	00	230	00
23.3	0.2	00	18	08	0.0	00	10.0	16	00	00	00	00	00	24	31	02	00	00	00	00
24.3	3.4	0.0	3.0	0.0	0.0	0.0	06	3.2	12	00	00	00	00	00	00	00	00	03	00	00
25.3	2.2	00	2.0	0.0	0.0	0.0	6.6	1.6	00	00	03	00	00	00	00	00	00	31	00	00
26.3	3.4	2.0	3.8	0.0	0.0	0.0	0.2	3.4	00	00	00	00	00	32	00	00	02	00	00	00
27.3	0.0	1.5	158	00	0.0	0.0	00	00	00	0.0	0.0	00	00	204	00	06	70	00	00	1.4
28.3	7.0	30.6	1.0	282	0.0	23.0	00	11.0	00	5.9	1.9	00	00	42	00	00	8.5	00	00	0.8
29.3	04	0.0	0.4	1.6	00	0.0	0.0	13.4	359	00	00	00	00	00	00	02	0.0	77	00	46
30.3	8.4	0.0	7.0	00	0.0	0.0	0.0	21.2	83	00	00	00	00	00	00	72	0.0	32	00	12.2
31.3	0.2	0.0	00	0.0	0.0	00	00	0.4	0.0	00	00	10	00	0.2	00	12	00	109	95	00
1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	20	0.0	00	00	06	00	00	00	00	00	18	00	00
2.4	7.6	0.0	00	00	0.0	00	0.0	5.4	118	00	00	00	00	02	00	72	00	00	00	15
3.4	0.8	0.0	39.2	0.0	0.0	0.0	0.0	0.0	10.7	00	00	34	00	86	00	02	127	00	00	00
4.4	00	0.0	00	00	0.0	0.0	00	06	00	00	00	44	14	00	00	00	64	00	00	00
5.4	0.0	0.0	00	0.0	0.0	00	0.0	0.6	0.0	00	00	00	133	0.8	00	02	48	00	00	9.1
6.4	0.0	0.0	00	0.0	0.0	00	00	02	00	00	00	00	26	02	00	72	16	00	00	128
7.4	0.0	00	00	00	00	00	00	0.2	00	69	00	28	18	80	00	108	1.2	00	00	187
8.4	0.0	00	0.0	0.0	0.0	00	00	04	00	00	00	00	06	06	00	208	02	00	00	00
9.4	0.0	00	00	0.0	00	00	00	02	00	00	134	24	03	64	00	17.2	02	00	00	00
10.4	8.6	0.6	80	0.0	0.2	00	00	0.2	00	00	00	70	66	2.2	00	10	00	00	00	02
11.4	0.2	38	00	00	0.4	00	00	00	00	04	00	00	93	154	00	14	00	00	00	05
12.4	0.0	02	00	00	0.2	00	00	00	154	00	00	20	18	82	23	00	00	00	00	16
13.4	00	12.6	00	00	50	00	0.0	00	18	00	00	08	09	0.2	02	00	00	00	00	52
14.4	00	00	61	00	00	0.0	00	00	00	17	00	17.2	58	00	216	00	00	00	00	82
15.4	0.0	16	00	00	4.0	00	08	00	00	03	00	00	28	00	00	00	00	00	00	173
16.4	0.0	06	00	00	46	00	240	184	00	00	00	00	96	00	159	00	00	00	00	08
17.4	0.0	00	00	00	48	00	54	00	00	00	00	00	19	00	96	00	00	00	00	51
18.4	0.0	00	00	00	00	00	08	00	00	00	00	00	00	00	26	00	00	00	00	00
19.4	00	00	00	00	00	00	00	00	00	00	00	00	03	00	68	00	00	00	00	05
20.4	00	00	00	00	00	00	00	00	00	00	00	00	00	00	03	04	00	00	00	00
21.4	0.0	36	00	00	00	00	00	00	00	11	00	02	196	00	72	08	00	00	00	00
22.4	0.0	160	00	00	00	00	00	00	00	00	00	28	43	00	02	26	00	00	00	00
23.4	00	02	80	00	00	00	00	00	00	150	00	00	03	00	99	22	110	00	00	00
24.4	00	236	00	00	00	00	00	00	00	48	00	40	00	00	00	06	16	00	00	00
25.4	00	04	00	00	00	00	00	00	00	122	00	54	87	00	00	168	130	00	00	02
26.4	00	50	00	00	00	00	00	00	00	376	00	154	00	00	00	04	0.2	00	114	00
27.4	00	02	69	0.0	00	00	00	02	00	178	00	176	00	00	00	52	00	00	00	50
28.4	00	02	40	7.5	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
29.4	00	00	00	00	00	00	00	02	00	00	00	182	00	00	00	00	00	00	00	19
30.4	00	04	00	00	216	00	0.0	00	00	00	00	00	31	00	00	00	00	00	00	00

15	00	30	25	00	19	00	00	02	00	00	00	00	00	00	00	00	00	00	00	00
25	00	00	25	00	00	16	00	02	00	00	00	00	03	00	00	00	00	00	00	00
35	00	00	00	00	02	00	00	00	00	00	00	00	00	00	00	00	00	00	00	16
45	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	37
55	00	00	67	10	59	80	00	00	00	00	00	136	08	00	00	00	00	00	00	00
65	00	00	00	00	00	28	00	00	00	00	00	86	00	00	00	00	00	35	10	108
75	00	00	00	00	08	00	00	00	00	00	150	00	00	00	00	00	00	00	31	00
85	00	00	00	00	00	04	00	00	280	00	54	36	00	46	00	00	00	01	00	00
95	00	00	00	00	00	10	00	00	98	00	480	134	00	02	00	00	00	00	00	00
105	00	20	10	00	00	02	00	00	381	00	22	00	00	10	00	00	00	00	09	00
115	00	106	30	00	00	08	00	02	00	00	228	38	00	00	00	00	00	00	03	00
125	00	94	59	00	00	00	00	52	00	00	18	26	00	00	00	06	00	00	00	89
135	00	00	00	00	00	00	00	56	00	00	04	00	00	00	00	00	00	00	00	125
145	00	00	00	00	00	00	00	12	00	00	00	00	00	00	00	26	00	00	00	264
155	00	02	00	00	00	00	00	16	00	00	00	00	00	00	00	00	00	00	00	00
165	10	00	08	00	00	00	00	04	00	00	00	00	00	00	00	00	00	00	00	41
175	04	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
185	278	00	00	13	00	00	00	00	00	00	00	00	00	00	00	06	00	00	00	00
195	14	00	00	00	00	00	00	00	00	00	02	00	00	00	00	24	00	00	00	00
205	88	00	00	31	00	00	00	00	00	00	02	02	00	04	00	00	00	00	00	00
215	08	00	00	34	00	00	00	00	00	25	00	02	00	06	00	00	00	00	00	00
225	182	00	00	194	00	00	00	00	00	00	62	00	00	32	00	00	00	00	00	00
235	48	00	00	193	00	00	00	00	00	00	08	00	00	02	00	00	00	00	00	00
245	76	00	00	75	00	00	00	00	00	39	00	00	00	12	00	00	00	00	00	00
255	82	00	00	42	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
265	00	00	00	42	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
275	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
285	00	00	00	00	00	00	00	00	00	17	00	00	00	00	00	00	00	00	00	00
295	02	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
305	00	00	00	00	00	00	00	00	00	00	14	00	00	00	00	00	00	00	00	00
315	00	00	00	00	00	00	00	00	00	25	00	00	00	00	00	00	56	00	00	00
16	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
26	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
36	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
46	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
56	00	00	00	00	13	00	00	00	00	00	00	00	00	14	00	00	00	00	00	13
66	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	101	00	00
76	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
86	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	86	00	00	00	00
96	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
106	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
116	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
126	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
136	00	00	00	00	00	00	00	00	00	00	00	00	00	44	00	00	00	00	00	00
146	02	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
156	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
166	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
176	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
186	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
196	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
206	02	01	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
216	00	00	00	00	00	00	00	00	00	00	00	00	308	00	00	00	00	00	00	00
226	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
236	00	24	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
246	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
256	00	00	00	00	00	00	00	00	00	00	00	00	08	00	00	00	00	00	00	00
266	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
276	00	00	00	11	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
286	10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
296	02	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
306	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

17	0.0	00	00	00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	0.4	00	0.0	0.0	0.0	0.0	00	0.0
27	0.0	00	00	00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	00	00	02	00	0.0	00
37	50	0.0	00	0.0	00	0.0	0.0	00	00	0.0	00	16	00	00	0.0	0.0	0.0	07	0.0	0.0
47	0.0	00	00	0.0	00	0.0	0.0	0.0	0.0	00	0.0	00	00	0.0	0.0	00	0.0	0.0	00	0.0
57	32	00	0.0	02	0.0	00	0.0	20.5	0.0	00	0.0	00	0.4	0.0	0.0	00	0.0	00	0.0	0.0
67	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	00	00	0.0	0.0	0.0	0.0	0.0	00	0.0	0.0
77	0.0	0.0	0.0	00	0.0	00	0.0	0.0	00	0.0	0.0	0.0	00	0.0	0.0	0.0	0.0	00	0.0	00
87	0.6	00	00	0.0	0.0	00	0.0	0.0	00	00	0.0	00	0.0	0.0	00	0.0	0.0	3.1	00	00
97	00	00	00	00	0.9	00	0.0	00	0.0	0.0	00	00	0.0	0.0	00	00	0.0	0.0	00	00
107	0.0	00	00	00	21.3	0.0	0.0	0.0	0.0	00	00	00	0.0	00	0.0	0.0	00	00	00	00
11.7	00	0.0	0.0	0.0	10.2	0.0	0.0	0.0	0.0	0.0	1.7	00	0.0	00	0.0	0.4	0.0	00	0.0	00
127	00	00	0.0	0.0	0.0	00	0.0	0.0	0.0	0.0	0.0	1.2	0.0	00	0.0	00	00	00	00	0.0
137	0.0	00	00	0.0	0.0	00	0.0	0.0	0.0	0.0	03	22	0.0	00	00	0.0	00	0.0	00	0.0
147	00	00	00	00	0.0	0.0	10	0.0	0.0	0.0	00	00	0.0	00	00	0.0	7.4	0.0	0.0	0.0
157	00	00	0.0	0.0	7.2	00	0.0	00	0.0	0.0	0.0	0.0	00	00	6.1	18	00	0.0	00	00
167	4.0	0.0	0.1	0.0	6.7	72	0.0	0.0	0.0	0.0	0.1	00	00	0.0	08	04	0.0	0.0	00	0.0
177	00	00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	1.6	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
187	00	0.0	00	0.0	5.1	0.0	0.0	00	0.0	0.0	00	00	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0
19.7	0.0	0.0	00	00	3.4	0.0	1.4	0.8	0.0	0.0	0.0	00	2.0	00	0.0	00	0.0	00	00	0.0
207	0.0	0.0	00	00	00	00	0.0	0.0	0.0	00	00	0.0	0.0	00	328	0.0	0.0	00	1.3	0.0
217	00	00	25	00	00	00	2.0	0.0	0.0	08	0.9	00	13	00	29	00	0.0	00	0.5	0.5
227	00	0.0	149	00	205	00	02	0.0	00	0.0	00	0.0	00	00	00	26	1.7	00	00	00
237	00	00	00	03	38	00	02	00	00	00	00	00	10	00	00	02	46	00	00	00
247	00	00	00	04	0.0	00	00	00	00	0.0	0.0	0.0	0.0	0.0	00	00	23	00	00	07
257	00	00	00	00	05	14	08	00	0.0	0.0	00	00	00	00	11.9	46	84	00	00	00
267	00	251	00	00	00	06	46	00	00	00	00	00	00	00	05	00	106	00	00	00
277	00	256	00	00	09	00	08	00	0.0	00	00	00	89	00	00	00	00	00	00	0.0
287	00	154	00	00	00	0.2	06	0.0	00	00	00	00	108	00	1.2	00	00	00	162	0.0
297	00	205	00	00	0.0	0.0	08	00	00	0.0	02	00	18	00	75	00	00	02	00	00
307	0.0	00	00	00	61	00	00	00	0.0	00	00	00	18	00	24	00	40	00	00	0.0
317	02	09	15	195	1.2	0.0	00	00	00	0.0	00	00	16	00	00	88	4.6	00	139	00
18	08	00	00	00	00	00	0.0	53.1	00	0.0	00	00	104	00	0.0	228	00	00	0.0	00
28	00	0.0	00	00	00	02	0.2	1.8	00	00	00	00	00	00	00	00	00	00	00	00
38	188	14	0.0	00	0.0	00	0.2	00	07	00	00	06	00	00	54	00	00	00	00	00
48	108	18	00	00	04	00	02	36	09	00	00	00	00	10	00	00	00	00	11	00
58	94	00	00	00	00	00	01	86	00	00	00	00	00	24	0.5	00	02	00	00	00
68	172	00	00	04	00	00	22	00	16	00	00	00	00	3.2	00	00	26	00	00	00
78	266	18.2	00	13	00	00	04	00	00	00	00	00	00	1.2	00	00	00	00	00	00
88	24	36	00	00	00	14	00	00	216	00	00	00	00	02	00	00	00	00	02	216
98	02	18	00	00	00	02	06	00	00	06	00	00	00	00	00	00	00	0.2	02	169
108	00	180	14	00	00	04	56	00	00	06	00	00	14	00	00	08	00	47	266	00
118	00	72	05	00	88	0.2	36	00	00	04	00	00	00	14	00	00	00	00	293	00
128	04	5.4	00	97	02	00	122	00	00	00	03	00	00	0.2	18	00	00	00	167	00
138	34	00	47	104	00	00	10	00	00	96	137	182	00	182	00	00	00	131	108	00
148	28	00	00	139	00	06	16	90	00	252	18	02	00	08	00	00	04	58	164	09
158	00	70	00	540	00	02	20	00	00	112	00	00	00	00	00	00	00	00	16	00
168	00	198	00	459	00	00	26	139	00	300	00	00	99	00	67	00	00	00	04	00
178	00	07	00	02	18	88	00	00	00	04	00	02	348	00	04	00	00	00	72	00
188	00	00	00	92	00	43	0.2	36	00	02	00	00	44	00	11	00	00	00	00	00
198	00	09	00	00	00	144	00	450	00	00	00	00	02	00	07	00	00	00	00	00
208	06	05	00	00	189	00	00	41	00	0.2	00	00	00	00	00	00	00	00	00	00
218	02	160	00	13	00	194	00	11	00	08	00	00	00	61	00	00	00	00	00	00
228	00	38	00	00	00	00	00	00	00	00	00	00	00	91	00	00	00	00	308	00
238	04	102	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	77	00
248	00	76	00	00	00	00	00	00	00	00	00	00	00	00	04	00	00	00	34	00
258	00	204	00	00	00	00	00	00	00	00	00	00	00	00	18	00	00	00	20	00
268	00	0.2	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	18	00
278	00	00	00	00	00	75	00	00	00	00	00	00	00	00	00	00	00	00	00	00
288	00	30	00	00	00	00	00	00	31	34	00	00	00	00	00	00	00	00	00	00
298	00	100	00	00	00	00	38	00	36	00	00	00	00	00	00	00	00	02	00	00
308	08	0.2	00	00	00	00	24	00	00	00	00	00	00	00	49	00	00	00	00	00
318	00	0.2	00	00	00	00	00	00	00	00	00	00	00	00	137	00	00	00	00	00

1 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.3	0.0	0.0	0.0	1.1	0.0
6 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0
7 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 9	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0
11 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 9	0.0	0.0	0.0	0.0	0.0	28.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0
18 9	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1	0.0
11.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
12 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16 10	0.0	0.0	0.0	0.0	0.0	0.0	40.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 10	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 10	0.0	0.0	0.0	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 10	0.0	0.0	0.0	38.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 10	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 10	0.0	4.2	0.0	60.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 10	0.0	0.0	0.0	12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 10	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 10	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30 10	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31 10	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.11	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.11	0.0	0.0	36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.11	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.11	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.11	0.0	0.0	0.0	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.12	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.12	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
5.12	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	0.0	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
9.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
10.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
11.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
12.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0
13.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0
16.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
17.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0
18.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
19.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
21.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.12	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0
30.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8	0.0	0.0	0.0	0.0	0.0	0.0
32.12			0.0				0.0				0.0				0.0				0.0	

A-12

Mind Rainfall mm	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
11	00	00	00	00	00	00	00	00	00	00	0	00	00	00	02	00	00	00	00	00
21	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	110	00	00	00
31	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
41	00	00	00	00	00	18	00	00	00	00	0	00	00	00	00	00	00	00	00	00
51	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
61	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
71	00	00	00	00	00	00	10.2	00	00	00	0	00	00	00	00	00	00	00	00	00
81	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	0.2	00	00	00	00
91	00	00	28	00	00	00	00	00	00	00	0	00	00	00	1.0	00	108	00	00	00
10.1	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
111	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
121	00	00	00	00	00	00	00	00	11.0	00	0	00	00	00	00	00	00	00	00	00
131	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	02	00	00	00	00
141	00	00	00	00	00	15.0	00	00	00	00	0	00	00	00	00	02	00	00	00	00
151	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	08	00
161	00	00	00	00	31	00	00	00	00	00	0	00	00	00	00	00	00	00	63	00
171	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
181	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	0.2	00
191	0	00	00	206	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
201	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
211	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
221	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
231	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	02	04	00	00	00
241	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	60	00	00	00
251	00	00	00	00	00	00	00	00	00	00	0	20	00	00	00	00	00	00	00	00
261	00	00	00	00	00	48	00	00	00	00	0	04	00	00	00	00	00	00	00	00
271	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
281	00	19	00	00	00	60	00	00	00	00	0	00	00	00	00	00	00	00	00	00
291	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
301	00	00	00	00	00	00	00	00	00	119	0	114	00	00	00	00	00	00	00	00
311	00	00	00	00	00	00	00	00	00	54.0	0	00	00	00	00	00	00	00	00	00
12	00	00	00	00	00	00	00	00	00	14	0	00	00	00	00	00	00	00	00	00
22	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	06	00	00	00
32	00	00	00	00	00	00	00	00	00	54	0	00	30	00	00	00	00	00	00	00
42	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	56	00	00	00	00
52	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
62	00	00	00	00	00	00	00	00	115	00	0	00	00	00	00	00	36	00	00	00
72	00	03	00	00	00	00	00	00	00	00	0	00	00	00	00	00	88	00	00	00
82	02	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
92	02	00	00	00	00	00	00	00	00	00	0	00	04	00	00	00	00	00	00	00
102	00	00	00	00	00	00	00	00	00	27	0	00	00	00	00	00	00	00	00	00
112	00	25	00	00	00	00	00	00	48	86	0	00	00	00	00	00	00	00	00	14
122	00	00	00	00	00	00	00	00	96	00	0	00	00	00	00	00	00	00	00	00
132	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
142	00	00	00	00	38	00	00	00	00	00	0	00	00	00	00	00	46	00	00	00
152	00	00	00	00	00	00	00	00	00	00	0	00	00	00	04	00	00	76	00	00
162	00	00	00	00	00	00	00	00	00	00	0	00	00	00	36	00	00	00	00	00
172	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
182	00	00	00	00	00	00	70	00	00	00	0	00	76	00	00	00	00	00	00	00
192	16	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
202	00	00	00	00	00	00	00	00	00	00	0	00	02	00	00	00	00	00	00	00
212	54	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	38	00	00	00
222	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	86	00	00	00
232	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
242	00	00	00	00	64	00	00	00	00	00	0	00	00	00	08	00	00	19	00	00
252	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	26	00	00
262	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
272	00	00	00	00	00	00	46	00	00	00	0	54	34	00	00	00	00	00	00	00
282	00	00	00	29	00	00	18	00	00	00	0	02	00	00	8.2	00	00	00	00	00

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13	00	00	20	00	194	0.0	90	0.0	0.0	00	0	00	00	00	0.0	0.0	00	00	0	00
23	00	00	00	0.0	0.5	0.0	0.0	5.0	0.0	0.0	0	00	0.0	0.0	0.0	0.0	00	00	0.0	0.0
33	04	00	22.6	00	00	00	0.0	02	27.3	0.0	0	00	94	0.0	0.0	0.0	2.0	00	0.0	0.0
43	0.0	00	0.0	0.0	00	00	0.0	13.2	0.0	0.0	0	4.0	190	00	0.0	0.0	0.0	0.0	00	00
53	1.2	00	00	00	0.0	00	0.0	22	3.9	00	0	0.2	0.0	00	0.0	0.0	00	00	0.0	0.0
63	00	00	00	00	0.0	00	00	00	0.0	0.0	0	0.0	00	00	0.0	0.0	0.0	0.0	00	0.0
73	00	00	00	00	0.0	00	0.0	00	28	00	0	0.0	02	12	0.0	0.0	06	17	0.0	00
83	00	00	00	00	0.0	0.0	00	0.0	11	59.8	0	00	00	04	0.0	00	00	237	0.0	00
93	00	00	0.0	0.0	00	00	0.0	00	00	00	0	00	00	26	00	0.0	00	00	0.0	00
103	00	00	00	00	00	00	0.0	00	0.0	00	0	00	00	0.0	00	00	0.0	00	00	00
113	00	00	0.0	00	4.9	00	0.0	02	0.0	00	0	00	00	00	0.0	2.4	0.0	20	00	00
123	00	00	04	00	34	11.7	4.4	0.0	0.0	72.9	0	0.0	02	00	00	0.0	00	00	0.0	0.0
133	00	00	00	00	00	00	0.4	32	0.4	71.1	0	00	04	00	00	0.0	0.0	00	0.0	0.0
143	00	00	0.0	00	0.0	00	08	148	00	13.1	0	0.0	0.0	00	0.0	00	0.2	0.0	0.0	0.0
153	0.0	00	16	00	00	00	00	1.0	0.0	0.0	0	00	0.6	0.0	00	2.6	2.6	0.0	00	0.0
163	00	00	132	00	0.0	00	00	06	0.0	00	0	00	114	0.0	0.0	4.4	0.0	350	0.0	0.0
173	00	00	06	0.0	00	00	00	14.0	00	0.0	0	04	00	12	0.0	7.6	00	28	00	0.0
183	00	00	00	11	00	0.0	00	216	00	00	88	00	0.0	28	0.0	0.0	00	0.0	00	00
193	194	26	00	00	00	00	00	2.2	0.0	0.0	06	02	00	04	00	3.0	00	00	0.0	00
203	54	131	0.0	00	00	00	00	0.2	0.0	0.0	0	00	0.0	00	0.0	0.0	0.0	00	7.1	00
213	06	00	0.0	0.0	00	00	178	00	00	0.0	0	3.4	10	0.0	02	0.0	0.0	0.0	0.0	00
223	02	00	02	00	00	00	0.0	00	0.0	0.0	0	00	00	00	1.0	00	240	00	280	00
233	04	00	00	06	00	00	64	84	00	00	12	00	00	00	12	0.0	40	00	00	00
243	24	00	00	00	00	00	100	20	15	00	02	00	00	1.6	00	48	00	07	00	00
253	00	00	16	00	00	00	64	126	00	00	0	38	00	7.2	00	00	00	69	00	00
263	00	15	150	00	00	00	00	00	00	0.0	0	40	00	00	00	00	00	00	00	00
273	02	11	00	00	00	00	00	20	00	00	0	04	00	00	0.2	12	00	00	00	17
283	46	374	00	344	00	270	00	200	00	185	0	00	00	36	76	00	16	00	00	09
293	10	00	56	19	00	00	00	28	439	00	0	02	00	00	136	64	00	176	00	56
303	00	112	18	00	00	00	00	76	101	00	0	04	00	00	0.0	02	12	73	00	150
313	00	290	06	00	00	00	00	18	00	00	0	06	0.0	00	00	0.0	00	166	116	00
14	36	151	132	00	23	00	00	00	00	00	0	46	0.0	00	0.0	74	38	25	00	0.0
24	48	157	00	00	00	00	00	18	131	00	0	122	02	00	00	68	00	00	00	1.6
34	08	125	00	00	00	00	00	28	118	0.0	0	20	00	00	00	00	122	00	00	00
44	00	00	10	00	00	00	00	12	00	00	0	18	18	00	1.2	00	00	00	00	00
54	00	15	00	00	00	00	00	40	00	00	0	04	16	10	10	00	00	00	00	101
64	00	00	28	00	00	00	0.0	192	00	0.0	0	108	66	56	00	124	2.2	00	00	141
74	316	00	00	00	00	00	00	00	00	77	0	30	136	58	00	142	80	00	00	206
84	04	04	00	00	00	00	00	00	00	00	0	02	98	14	240	410	00	00	00	00
94	60	12	00	00	00	00	00	00	00	00	0	24	86	56	00	104	00	00	00	00
104	00	28	00	00	00	00	00	00	00	00	44	10	02	00	00	12	02	00	00	02
114	12	80	00	00	00	00	00	00	00	05	5	00	136	14	00	10	00	00	00	05
124	00	02	00	00	00	00	00	14	170	00	0	58	00	02	182	00	00	00	00	18
134	00	28	00	00	00	00	00	00	20	00	0	48	00	24	1.2	00	00	00	00	58
144	00	00	00	00	00	00	00	00	00	19	0	00	32	00	00	00	00	00	00	90
154	00	22	00	00	34	00	00	00	00	04	0	00	18	00	00	00	00	00	00	191
164	00	0.2	00	00	40	00	155	00	00	00	1	00	124	00	140	00	00	00	00	09
174	00	08	00	00	40	00	131	00	00	00	0	00	62	00	84	00	00	00	00	57
184	00	00	78	00	00	00	126	00	00	00	0	00	06	00	23	00	00	00	00	00
194	0	00	00	00	00	00	12	00	00	00	0	00	00	00	60	00	00	00	00	05
204	00	24	10	00	00	00	00	00	00	00	0	00	00	00	03	00	00	00	00	00
214	00	00	00	00	00	00	00	00	00	13	0	06	60	02	63	00	00	00	00	00
224	00	00	20	00	00	00	00	00	00	00	0	324	00	00	02	00	28	00	00	00
234	00	88	16	00	00	00	00	00	00	166	0	00	96	00	87	00	30	00	00	00
244	00	00	248	00	00	00	00	00	00	53	0	192	00	00	00	113	38	00	00	00
254	00	164	00	00	00	00	00	00	00	135	0	04	96	00	00	100	00	00	00	02
264	00	00	00	00	00	00	00	00	00	416	0	28	00	00	00	59	00	00	126	00
274	00	00	06	00	00	00	1.2	00	00	196	0	00	00	00	00	00	00	00	00	55
284	04	02	46	83	00	00	00	00	00	00	0	38	00	00	00	00	10	00	00	00
294	00	0.2	70	00	00	00	00	00	00	00	0	142	00	00	00	00	00	00	00	21
304	02	00	08	00	48	00	00	00	00	00	0	00	34	00	00	00	00	00	00	00

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15	00	00	172	0.0	8.4	08	00	00	0.0	00	0	00	0.0	00	00	00	00	00	00	0.0
25	00	00	122	00	86	24	0.0	0.0	0.0	00	0	00	04	0.0	0.0	00	00	00	00	0.0
3.5	00	00	84	0.0	9.2	0.0	00	00	0.0	00	0	00	00	00	00	00	00	00	00	24
45	00	00	74	00	56	3.4	00	00	00	0.0	0	0.4	00	00	00	00	00	0.0	00	55
55	08	00	36	1.5	18	44	0.0	00	00	0.0	0	74	13	00	00	00	00	0.0	0.0	00
65	46	00	140	00	40	34	00	0.0	00	00	3	50	00	00	00	00	00	67	15	161
75	04	00	2.6	00	00	00	00	00	0.0	00	68	12	00	0.0	00	00	00	00	47	00
85	02	00	1.4	00	00	00	00	00	420	00	04	170	00	02	00	00	00	01	00	00
95	306	06	00	0.0	0.0	250	00	00	147	00	2.4	122	00	172	00	0.0	00	00	00	00
105	00	186	50	00	0.0	104	00	430	573	00	64	42	00	04	00	00	00	00	14	00
115	00	00	30	00	02	06	00	00	0.0	00	15.8	7.8	00	50	00	00	02	00	04	0.0
125	00	00	28	00	02	0.0	0.0	00	00	0.0	17	14	10	1.2	00	00	80	00	00	133
135	00	00	06	0.0	22	00	00	0.0	00	00	308	00	36	00	00	00	42	00	00	18.8
145	00	00	00	0.0	00	00	00	00	00	00	0	00	06	00	00	02	00	00	0.0	406
155	00	00	02	00	0.0	00	00	00	00	0.0	72	02	06	00	00	00	08	00	00	00
165	00	00	00	00	00	00	00	00	0.0	00	2	00	00	0.0	00	00	00	00	00	6.1
175	00	00	00	00	00	00	14	00	00	00	06	00	02	00	00	00	00	00	00	00
185	0.0	00	16	19	00	00	00	00	00	0.0	0	12	00	00	00	00	00	00	00	00
195	0	0.0	0.0	00	00	00	00	0.0	0.0	00	0	1.4	00	00	00	00	00	00	00	00
205	00	00	00	4.7	00	00	00	0.0	00	0.0	0	28	00	2.4	00	00	00	00	00	0.0
215	00	00	00	51	00	0.0	00	00	0.0	37	0	00	00	06	00	0.0	00	00	00	00
225	127	00	00	292	00	0.0	0.0	0.0	00	00	0	00	00	30	00	00	00	00	00	00
235	97	0.0	00	289	00	00	00	0.0	00	00	14	00	00	12	00	02	00	00	00	00
245	114	00	00	113	00	00	00	00	00	58	0	00	00	02	00	00	00	00	00	00
255	00	00	00	64	00	00	00	00	00	00	56	00	00	100	00	00	00	00	00	00
265	02	00	00	64	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
275	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
285	00	00	00	00	00	00	00	00	00	25	0	00	00	00	00	00	00	00	00	0.0
295	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	0.0
305	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	0.0
315	00	00	26	0.0	00	00	00	00	00	38	0	00	00	00	00	00	00	00	00	00
16	20	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	0.0
26	00	00	0.0	00	00	00	00	00	00	00	12	00	00	00	00	00	00	00	00	00
36	00	00	00	00	0.0	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
46	00	00	00	00	00	00	00	00	00	0.0	0	00	00	00	00	00	00	00	00	00
56	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	04	00	00	00	07
66	00	14	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	34	00	00
76	00	0.2	32	00	00	00	00	00	00	00	0	00	00	00	00	32	00	00	00	00
86	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
96	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	16	00	00	00	00
106	00	00	00	00	02	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
116	16	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
126	00	00	00	00	00	00	00	00	00	00	0	00	00	138	00	00	00	00	00	00
136	00	00	00	00	00	00	00	00	00	00	0	00	00	50	00	00	00	00	00	00
146	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
156	00	00	00	00	12	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
166	00	00	00	00	00	00	00	00	00	00	36	00	00	00	00	00	00	00	00	00
176	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
186	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
196	0	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
206	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
216	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
226	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	08	00	00	00
236	88	1.2	00	00	00	00	00	00	00	00	0	00	00	00	00	00	10	00	00	00
246	80	00	12	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
256	00	00	00	00	00	00	00	00	00	00	0	00	44	00	00	00	66	00	00	00
266	00	00	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
276	74	00	06	05	06	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
286	00	00	00	00	00	00	00	00	00	00	0	00	50	00	00	00	00	00	00	00
296	00	00	18	00	00	06	00	00	00	00	0	00	00	00	00	00	00	00	00	00
306	00	00	00	00	00	00	00	00	00	00	0	00	12	00	00	00	00	0	00	00

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1.7	00	0.0	0.0	0.0	0.0	42	00	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
27	00	00	0.0	00	0.0	2.0	00	0.0	00	0.0	0	00	0.0	00	0.0	0.0	0.0	0.0	00	00
37	00	00	00	00	0.0	0.2	0.0	00	0.0	0.0	0	1.2	0.0	0.0	0.0	0.0	00	1.4	0.0	0.0
47	00	00	06	0.0	00	0.0	0.0	00	0.0	0.0	0	56	00	0.0	00	0.0	0.6	00	00	0.0
57	20	00	00	0.2	0.0	00	0.0	272	0.0	0.0	0	00	00	0.2	0.0	0.0	0.0	0.0	0.0	0.0
67	0.0	00	00	00	00	00	0.0	0.0	00	00	0	5.4	3.6	0.0	00	0.0	00	0.0	00	0.0
77	00	00	00	00	1.2	12	00	00	00	0.0	0	00	0.4	3.2	00	00	02	00	0.0	00
87	00	00	0.0	00	00	00	0.0	00	00	0.0	0	02	0.8	0.0	0.0	00	44	54	0.0	0.0
97	00	00	0.0	0.0	0.0	00	0.0	0.0	00	0.0	0	00	3.0	0.0	6.4	00	0.0	00	00	0.0
10.7	00	0.0	0.0	0.0	110	00	00	00	00	00	0	0.0	0.2	0.0	0.0	0.4	00	00	00	0.0
11.7	00	00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	00	0.0	0.0	0.0	0.2	00	0.0	0.0	0.0
127	00	0.0	0.0	0.0	00	0.0	0.0	0.0	0.0	0.0	5	0.0	00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
137	00	00	0.0	0.0	0.0	00	00	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	0.0
147	00	00	0.0	00	52	00	0.4	0.0	0.0	0.0	0	00	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.7	00	00	00	00	9.2	00	0.0	00	00	00	0	6.6	0.0	0.0	0.0	0.0	0.0	00	00	0.0
167	00	00	01	0.0	0.0	5.0	0.0	0.0	0.0	00	0	02	0.0	0.0	0.0	0.0	00	0.0	0.0	0.0
177	00	0.0	00	0.0	0.0	0.0	00	0.0	00	0.0	0	16	0.0	0.0	0.0	0.0	00	0.0	0.0	00
187	00	00	00	0.0	04	1.4	00	00	0.0	0.0	0	3.8	00	0.0	0.0	0.0	0.0	00	0.0	0.0
197	0	00	00	0.0	23.4	0.0	2.4	0.8	0.0	0.0	1.8	0.2	0.0	0.0	1.6	00	0.0	00	00	0.0
207	00	0.0	0.0	0.0	02	0.0	0.0	1.1	0.0	00	2.8	0.0	0.0	0.0	4.4	0.0	0.0	0.0	1.8	0.0
21.7	00	0.0	3.3	0.0	00	0.0	2.8	00	00	0.8	2	00	0.0	0.0	0.0	0.0	0.0	00	0.7	0.7
227	0.0	00	19.7	0.0	0.0	0.2	1.6	00	0.0	0.0	0	00	04	00	0.0	00	1.7	00	00	0.0
237	02	00	00	04	76	0.0	00	00	00	00	0	00	14	00	00	0.0	4.6	00	00	0.0
247	00	00	0.0	0.5	168	00	00	00	00	00	0	0.0	72	0.0	00	0.0	2.3	00	00	1.0
257	00	00	00	00	34	28	9.2	00	00	00	0	00	3.8	00	11.6	00	84	0.0	00	0.0
267	66	332	00	0.0	04	04	98	00	0.0	00	0	00	64	00	00	0.0	106	0.0	00	00
277	06	339	00	00	1.8	124	324	00	00	0.0	0	00	08	00	0.0	0.0	00	00	00	00
287	02	204	00	00	0.0	9.0	26	00	00	00	0	00	02	00	00	00	00	0.0	215	00
297	00	27.2	00	00	2.2	240	15.4	00	00	00	02	00	00	00	00	0.0	00	04	0.0	0.0
307	02	00	00	00	64	0.6	00	00	0.0	00	0	00	238	00	0.0	00	40	00	0.0	00
317	04	1.2	20	258	178	16	00	00	0.0	00	0	00	32	00	00	00	46	00	185	0
18	08	0	00	00	6.4	00	00	507	00	00	0	00	00	00	0.0	91	0.0	0.0	00	0.0
28	04	0	00	00	0.0	02	00	17	00	0.0	0	00	10.0	0.0	00	00	0.0	0.0	0.0	00
38	150	1.4	00	00	00	00	1.8	00	0.7	00	0	00	12	00	30	2.5	0.0	00	0.0	0.0
48	9.2	1.7	00	0.0	02	00	38	34	09	00	0	00	90	13	00	2.1	00	00	10	00
58	54	0	00	00	10	00	00	83	00	00	0	48	04	03	03	00	17.2	00	00	00
68	316	0	00	03	16	00	4.8	00	09	0.0	104	00	08	137	00	00	10.2	00	00	00
78	00	17.4	00	12	00	00	32	00	00	1.2	02	00	36	14	00	80	10	00	00	00
88	155	34	00	00	08	0.2	00	00	206	00	02	00	00	00	00	02	00	00	01	20.7
98	00	17	00	00	122	00	16	00	00	14	04	00	00	00	00	00	00	02	01	162
108	00	17.2	14	00	58	08	228	00	00	68	0	00	00	166	00	00	00	7.7	254	00
118	00	69	05	00	22	00	14	00	00	00	0	00	22	94	00	20	6.2	00	280	00
128	17	5.2	00	93	00	60	60	00	00	00	164	00	00	24	10	24	10	00	160	00
138	25	0	45	99	00	00	36	00	00	90	66	36	00	29	00	00	00	215	103	00
148	102	0	00	132	00	56	00	86	00	48	62	82	00	00	00	02	00	95	156	09
158	00	67	00	516	232	20	18	00	00	18	0	74	00	00	00	00	36	00	15	00
168	00	189	00	438	38	10	116	132	00	274	0	60	00	00	37	00	1.2	00	03	00
178	00	07	00	02	02	30	00	00	00	12	0	108	40	00	02	00	100	00	69	00
188	00	0	00	87	18	70	00	34	00	00	0	00	00	00	06	35	00	00	00	00
198	08	09	00	00	22	44	02	430	00	00	0	00	00	00	04	00	00	00	00	00
208	00	05	00	00	02	08	00	40	00	00	0	60	04	00	00	00	00	00	00	00
218	00	153	00	09	00	58	00	10	00	118	0	00	36	07	00	04	00	00	00	00
228	00	488	00	00	00	38	00	00	00	00	0	00	82	10	00	13	00	00	294	00
238	06	34	00	00	00	00	00	00	00	00	0	02	78	00	00	00	00	00	74	00
248	00	12	00	00	00	00	00	00	00	00	0	00	00	00	02	00	00	00	33	00
258	26	29	00	00	00	00	00	00	00	00	0	00	00	00	10	00	00	00	19	00
268	00	0	00	00	00	00	00	00	00	00	0	00	274	00	00	00	00	00	17	00
278	00	0	00	00	00	00	00	00	00	00	0	00	00	00	00	00	00	00	00	00
288	00	0	00	00	00	00	00	00	29	00	0	00	00	00	00	38	00	00	00	00
298	00	0	00	00	00	00	00	00	34	04	0	06	00	00	00	00	00	01	00	00
308	18	0	00	00	00	00	00	00	00	00	0	04	00	00	27	00	00	00	00	00
318	04	0	00	00	00	00	00	00	00	00	0	00	00	00	76	00	0	00	00	00

1.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.9	0.2	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.9	0.0	0	0.0	0.0	0.0	0.0	35.8	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.9	0.0	0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	2.9	0.0	0.2	0.0	0.0	0.0	1.1	0.0
6.9	0.0	1.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0	1.8	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0
7.9	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0
8.9	8.6	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.9	0.0	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0
11.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.9	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.6	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0
18.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.9	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	0.0	0.0
21.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0
1.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0	0.0
2.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.4	0.0
10.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
11.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
12.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	44.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	15.3	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.1	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.1	0.0	0	0.0	0.0	0.0	0.0	17.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.1	0.0	0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.1	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.1	0.0	0	0.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.1	0.0	0	0.0	40.4	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.1	0.0	0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
26.1	0.0	0	0.0	62.6	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
27.1	0.0	0	0.0	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.1	0.0	0	0.0	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.1	0.0	0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.1	0.0	0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.1	0.0	0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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1 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 11	0.0	0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 11	0.0	0	37.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 11	0.0	0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 11	0.0	0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 11	0.0	0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 11	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 11	0.0	0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30 11	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 12	0.0	0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 12	0.0	0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 12	0.0	0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
6 12	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0
8 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0
9 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
10 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 12	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 12	0.0	0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
30 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31 12	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	24.8	0.0	0.0	0.0	0.0	0.0	0.0
32 12			0.0				0.0				0				0.0				0.0	
	0	1.9	2.8	20.6	3.1	27.6	10.2	0	11	65.9	0	13.8	0	0	1.2	0.8	28.2	0	7.3	0
	7.4	2.8	0	2.9	10.2	0	13.4	0	25.9	18.1	0	5.6	14.6	0	13	5.6	30	12.1	0	1.4
	35.8	95.9	65.2	38	28.2	38.7	55.2	135.6	91	235.4	10.8	17.6	42.2	21	23.8	32.6	38.2	114.278	46.7	23.2
	49	91.4	67.2	8.3	18.5	0	43.6	30.4	43.9	108.4	10.4	122.4	108.77	23.6	91.8	121.6	37	2.5	12.6	87.7
	70.6	19.2	82.6	95.4	40.2	50.4	1.4	43	11.4	15.8	99.4	62.2	7.7	41.4	0	0.4	13.2	6.8	8	102.8
	27.8	2.8	6.8	0.5	2	0.6	0	0	0	0	4.8	0	10.8	18.8	0	5.2	8.4	3.4	0	0.7
	10.2	115.9	25.7	26.9	10.7	6.5	76.6	29.1	0	0.8	22.4	24.8	55.6	3.4	24	0.6	41.4	7.2	42.5	1.7
	98.5	16.5	6.4	139.1	61.6	40.6	82.6	137.3	29.4	65.8	40.4	48	78.6	49.7	20.7	35.5	50.4	38	148.9	37.8
	8.8	28.8	0	0	0	1	35.8	0	0	0	0	3.4	2.9	7.2	4.6	0	5.8	0	2.1	0
	0	0	0	160.9	0	0	18	0	71.1	0	0	0	0	5.4	0	0	0	0	35.2	0
	0	0	45.2	2.9	5.4	0	2.8	0	5.8	0	0	0	0	0	0	0	0	0	0	0
	0	1.2	3.1	2.4	0	0	0	0	0	0	28	1.2	0	36.8	0	0.3	0	0.3	0	0
	308.1	524.9	305	497.9	276.2	223.9	319.6	375.4	392.1	510.2	216.2	299	320.97	207.3	179.1	202.6	250.6	185.578	303.3	265.3

A 18

mean TEMPERATURE

	1986	1987	1988	1989	1990	1991	1992	1993
01/01	14 8	14 35	13 7	12 6	13 4	13 6	15 2	15 6
02/01	14 8	15 75	13 8	13 3	14 2	15 7	15 5	15 9
03/01	14 8	13 45	13 9	14 1	15 7	15 3	14 7	16 6
04/01	14 8	12 7	14 7	14 8	16 1	15 8	13 7	16 4
05/01	14 8	13 85	14 8	14 6	15 6	17	13 1	16
06/01	14 8	15 55	15 1	13 6	14 9	14 8	10 2	15
07/01	14 8	14	15 4	12 3	14 5	13 4	11 7	14 7
08/01	14 8	15 9	15 8	14 3	14 9	15	14	16
09/01	14 8	13 95	15	13 5	15 5	14 2	12 7	16 3
10/01	14 8	14 4	14 1	13 9	16 1	15 9	13 1	15 5
11/01	14 8	12 7	15 3	14 9	13 5	15 5	12 7	15 3
12/01	14 8	13 65	15 6	13 5	12 8	16 6	12 4	15 8
13/01	14 8	10 75	13 7	13 7	15 1	16 9	12.2	15 8
14/01	14 8	10 85	14	14 5	16	17 1	13 5	12.5
15/01	14 8	9 6	15	13 5	15 9	16 8	14 6	11 5
16/01	14 8	7 6	17	15 1	16 6	17 3	14	12.1
17/01	14 8	5 05	16 4	14 5	15 5	16 9	16.3	12 8
18/01	14 8	5 5	16 2	12 3	15.2	17 1	17 1	12 4
19/01	14 8	4 7	13 6	10 5	11.3	17 1	16 4	14
20/01	14 8	4 55	10 9	12 9	12	16 7	16 5	13 9
21/01	14 8	8 9	13 5	13 2	14 2	16 7	17 2	14 2
22/01	14 8	10 55	14 2	13 4	14 9	16 7	17	14 7
23/01	14 8	11 85	14	13 6	16 5	17 6	16.3	15 3
24/01	14 8	12 95	14 6	12 3	17 2	18	15 1	14 7
25/01	14 8	14 4	16 3	11 5	17 3	17 8	14 1	13.3
26/01	14 8	15 5	17 4	11 4	15 8	17 6	13.9	12.1
27/01	14 8	16 55	15 7	13 1	15 4	16 7	14 2	13.4
28/01	14 8	16 9	17	14 6	16.9	13 9	15	13 8
29/01	14 8	14 05	15 6	14 7	15 6	14 6	15.1	14 8
30/01	14 8	10 45	15 2	13 8	12 3	15 8	16 1	16.2
31/01	14 8	10 75	16 4	15 4	13 4	16 9	16 2	17 5
01/02	14 9	10 25	17 3	17	15 6	16 9	16 2	17 7
02/02	13 3	10 55	17 4	17 3	17.2	16 5	16 7	18 1
03/02	13 6	11 95	18	16 9	18 2	16 9	17 2	17 2
04/02	14 3	11 95	15 7	15 5	19 4	16 6	17 3	16 5
05/02	16 0	10 65	14 4	14 3	17 4	17 1	16.2	16 5
06/02	17 2	10 4	14 6	14	15 1	17 7	16 8	12 8
07/02	16 1	11 45	15 7	13 3	14 1	17 7	17	8 7
08/02	16 6	13 75	17 3	14 1	14 5	16 6	17 1	12.8
09/02	17 5	15 55	17 2	15 2	17 1	16.2	16	13 6
10/02	18 7	18 25	17.2	15 9	17 3	15.2	16 5	14 5
11/02	17 4	17 6	16 5	16 5	18 8	15	16	14 2
12/02	16 1	15 7	17 4	16 7	17 8	16 1	12.8	13 4
13/02	17 1	15 1	18 1	17 5	17 1	15 3	14	16 4
14/02	15 0	13 85	18 6	15 8	20.1	15.2	15 7	16 4
15/02	16 9	14 25	18 6	15 7	17 6	15	15.7	17 1
16/02	15 9	15 1	17 8	16 3	17.2	12	15 4	17 2
17/02	16 1	16 35	18 3	15 8	17 1	14 3	14 7	16 5
18/02	15 7	16 25	17 7	16 3	16.2	15 9	15 8	17 4
19/02	15 0	15 9	17 9	17 3	18 1	17.2	15.8	17 2
20/02	13 1	18 15	16 7	17 1	17 1	16	15.3	18
21/02	14 7	16 35	16 5	16 6	16 3	16 3	15 8	18 8
22/02	14 7	17 95	16 6	16 8	15 4	17	17 9	18 2
23/02	15 0	16 8	17 1	15 7	16 8	16 4	19 4	17 8
24/02	14 4	17 1	15 3	14 8	17 5	17 5	19	16 8
25/02	16 3	17 3	16 5	15 7	17 4	17 6	19 3	13 9
26/02	17 2	18 4	17 1	15 6	17 9	17 1	19 3	14.4
27/02	15 9	18 1	16 4	16.5	16 9	17 4	17 6	14.1
28/02	15 9	16 3	16	15 1	17 6	18 8	16 6	14 4
			17 1				16.1	
01/03	17 2	18 7	19 1	18 20	18	17 7	16.9	14 6
02/03	14 0	17 1	19 1	18 20	16 8	18 6	17 3	14 1
03/03	10 6	18 8	18 7	18 20	15.1	18 5	17.2	14
04/03	14 3	17 05	19.2	18 20	15.1	19 1	14 9	14 7
05/03	16 6	17 6	19 5	18 20	16	19 5	15.9	17.1
06/03	17 0	19 35	19 6	18 20	18.5	18 9	17	18.2
07/03	16 5	16 5	20 9	18 20	19	17	18 4	19.1
08/03	17 5	18 7	21	18 20	20	15 1	18.8	19.5
09/03	17 0	19 6	20.9	18 20	20	17.2	19 4	19.9
10/03	19 3	17 6	21.2	18 20	18	18.2	19 6	19.9
11/03	19.5	17 8	20 1	18 20	19	18 1	19.1	20.1
12/03	19 5	18 6	19 9	18 20	19	17	18.1	20
13/03	19 9	18 65	19 8	18 20	18	18.6	16.9	18.9
14/03	20.3	16 85	19 6	18 20	20	18.2	17 7	19
15/03	20.2	15.5	19.6	18 20	18	17 6	19.2	19
16/03	20.1	18.3	17.5	18 20	20	17	20.3	19
17/03	20.0	19 05	16.6	18 20	19	17.3	19.8	18.3
18/03	18.1	17 15	18 1	18 20	20	18.5	19.7	19.8
19/03	19 7	17.35	18 2	18 20	21	20.2	18.2	20.1
20/03	20 0	17 35	18.9	18 20	21	20.6	19.1	19.3
21/03	18 4	19.3	20	18 20	20	21.1	17.8	18.8
22/03	18 3	19.1	20.1	18 20	19	22.1	18.7	20.1
23/03	18 4	18 9	20.2	18 20	19.5	22.4	20.2	19.2
24/03	18 9	17 9	18.1	18 20	19.4	19.1	21.2	19 6
25/03	19 9	18 6	18 2	18 20	20.2	18	20.8	19.6
26/03	19 7	19 45	19.9	18 20	20.2	18 3	19.3	19.6
27/03	20 9	20 45	21.2	18 20	18.4	18.3	19 9	18 4
28/03	18 6	18.2	20.6	18 20	16.3	17 6	18.9	16
29/03	19 3	18 05	20 2	18 20	18 3	18	19.8	16.2
30/03	20 4	19 1	20.2	18 20	18.6	17 3	18.1	16.9
31/03	21 6	17 15	20	18 20	19.1	15.1	17.8	17.1

01/04	20.1	19.65	20.4	18.15	19.3	17	19.8	19
02/04	18.5	18.2	19.8	19.15	18.1	17.5	19.7	17.1
03/04	20.1	19.15	20.2	17.2	16.7	19.3	19.6	16.2
04/04	17.6	18.8	21.2	16.8	17.5	20.9	19.7	17.1
05/04	17.2	20.7	19.7	16.25	17.3	21.6	19.7	15.9
06/04	16.5	17.2	18.2	14.8	17.9	22	17.8	15.1
07/04	17.8	18.8	18.7	11.35	18.7	22	17.6	17.9
08/04	16.1	16.1	20.1	11.45	19.3	21.9	18.4	18
09/04	17.0	18.05	19.6	12.7	19.7	21.3	17.7	18.1
10/04	14.7	17.35	19.6	16.1	18.2	21.7	18.5	18.3
11/04	16.3	18.05	17.6	16.3	18.8	20.1	19	17.5
12/04	16.8	17.65	18.3	17.75	19.1	21.5	18.9	16.9
13/04	18.5	17.1	16.1	18.75	18.8	20.2	19	15.6
14/04	15.3	20.5	19.2	18.8	18.9	19.5	18.9	14.5
15/04	17.0	18.15	18.2	19.25	19.4	19.4	20.2	12.3
16/04	17.3	17.85	17.5	18.1	20.4	20.6	19.5	14.1
17/04	17.6	18.5	16.7	17.9	20.5	20.2	20.8	13
18/04	18.4	19.15	17.4	18.65	20.6	20.9	21.6	14.6
19/04	18.0	19.05	18.2	19.6	20.4	22	20.3	13.9
20/04	18.8	20.25	17.2	20.7	20	21.3	20	16.2
21/04	18.1	18.2	17.9	18.75	20.1	21	19.3	18.8
22/04	18.0	17.8	17.5	19.25	20.2	20.9	21.6	19.1
23/04	18.1	17.85	18.6	15.25	16.4	20.5	22.7	20.3
24/04	19.6	17	18.5	17.25	14.6	20.5	20.6	19.9
25/04	19.7	18.8	19	14.6	17.1	20.5	18.6	18.8
26/04	20.9	20.85	19.1	14.15	17.3	21.3	18.6	19.6
27/04	19.9	19.6	19.6	15.65	18.3	20.3	21	18.8
28/04	19.4	19.2	19.7	17.5	17.2	20.6	21.4	18.6
29/04	20.1	18.75	20.1	17.8	18.6	20.7	20.9	17.7
30/04	18.8	18	20.2	18.4	20.4	20.8	21.8	18.3
01/05	20.3	18.15	19.7	17.5	21	21.3	21.1	20.3
02/05	20.4	19.1	19.2	17.2	19.1	22	21.1	20.1
03/05	20.1	21	19.8	16.95	20.5	22.8	21.1	18.2
04/05	19.5	21.05	20.5	18.2	21.7	22.7	21.1	19
05/05	20.7	20.3	20.8	19.65	21.6	20.5	21.1	20.2
06/05	19.4	19.75	21	17.55	21.8	19.4	21.1	19.6
07/05	19.6	20.85	20.6	17.55	22.7	17.4	21.1	19.7
08/05	20.4	21.35	20.3	16.6	22.4	18.5	21.1	21.4
09/05	20.4	18.45	20.8	16.95	21.1	19.4	21.1	20.1
10/05	21.4	19.15	21.5	16.35	22	20.6	21.1	21.1
11/05	22.8	18.6	22.1	17.35	21.8	21.4	21.1	21.8
12/05	22.0	19.15	22.6	20.4	21.6	22.2	21.1	19.6
13/05	22.5	17.95	21.9	20.45	22.3	23.1	21.1	17.6
14/05	21.9	19	22.7	21.35	22.1	21.9	21.1	17.3
15/05	22.3	18.45	22.7	20.9	21	21.4	21.1	17.8
16/05	22.1	16.95	21.6	21.3	20.3	23.9	21.1	16.8
17/05	19.4	18.05	21.1	19	21.8	23.6	21.1	18.3
18/05	19.5	17.55	21.4	20.65	21.3	23.9	21.1	19.4
19/05	21.0	18.65	21.3	19.45	21.5	22.1	21.1	20.2
20/05	20.3	19	22.2	18.45	21.8	21	21.1	20.3
21/05	20.6	20.55	22.8	17.9	21.2	23.8	21.1	20.6
22/05	21.6	18.45	22.8	16.4	21.3	22.6	21.1	21.1
23/05	19.8	18.95	21.7	17.55	22.1	23.9	21.1	21.3
24/05	19.0	19.65	22.1	18.5	22.9	22.8	21.1	20.8
25/05	21.4	19.15	22.4	20.45	21.3	22.6	21.1	20.1
26/05	19.0	20.2	21.7	18.75	22.4	21.8	21.1	21.2
27/05	18.7	20.1	21.3	19.4	22.8	21.1	21.1	21.9
28/05	19.2	20.3	21.6	18.9	23.4	23.4	21.1	22.6
29/05	20.3	20.7	21.6	19.1	24	22.5	21.1	21.4
30/05	21.2	22.3	21.8	19.35	23.5	23.6	21.1	21.7
31/05	20.1	23	22.8	18.85	21.3	22.9	21.1	22.6
01/06	18.9	23.2	22.7	22.1	22.2	21.5	22.2	22.7
02/06	18.7	22.4	22.5	21.7	22.2	22.2	22.2	23.3
03/06	20.5	21.8	22.7	21.8	22	22.5	22.2	23.1
04/06	19.9	21.6	23.3	22.8	21.2	21.9	22.2	22.9
05/06	19.6	21.1	22.4	22.2	20.8	21.9	22.2	21.8
06/06	21.3	21.4	22.5	20.7	22.4	22	22.2	21.8
07/06	22.7	23.5	21	19.7	23.4	22.2	22.2	22
08/06	20.8	22.6	23.8	21.7	22.7	21.4	22.2	22.3
09/06	20.8	23.4	24	22.3	22.6	22.2	22.2	22.1
10/06	21.3	24.8	23.9	22.7	22.7	23	22.2	22.2
11/06	21.0	25.3	23.5	22.6	21.6	23.9	22.2	22.6
12/06	20.3	24.3	22.6	23	22.1	24.1	22.2	22.3
13/06	20.4	24.7	23.2	23.2	23.6	23.9	22.2	22.2
14/06	21.4	21.5	23	22.4	23.5	24.1	22.2	22.4
15/06	23.6	23.8	23.5	22.4	24.3	23.9	22.2	23.4
16/06	21.1	23.3	23.8	22.6	22.9	24.3	22.2	23.6
17/06	20.9	23.7	23.5	21.5	22.7	23.8	22.2	24.4
18/06	22.6	23.8	24.6	20.7	23	23.4	22.2	23.6
19/06	20.3	23.4	24.7	21.2	22.7	22.7	22.2	23.3
20/06	22.3	23.5	23.3	22.5	23.5	23.6	22.2	23.5
21/06	24.0	23.3	22.1	22.8	22.4	24.3	22.2	22.7
22/06	21.7	22.8	21.5	22.4	22.5	24	22.2	21.8
23/06	22.9	21.8	22.3	21.4	22.9	24.2	22.2	21.1
24/06	20.9	21.6	22.2	21.5	23.5	24.7	22.2	21.5
25/06	21.8	21.1	23	21	23.6	23.8	22.2	22
26/06	23.3	22.1	22.7	22.2	23.6	24.7	22.2	22.2
27/06	23.7	22.4	22.5	22.9	23.7	23.8	22.2	23.5
28/06	24.5	23.3	22.3	23.2	24.2	24.6	22.2	23.2
29/06	24.7	23.8	22.4	23.6	24.1	25	22.2	24.2
30/06	22.9	23.9	22.4	22.5	24.2	22.2	22.2	24.1

01/07	22.0	22	22.3	23.6	23.4	24.2	22.5	23.7
02/07	21.3	23.05	22.9	24.1	22.1	23.1	22.5	23.2
03/07	20.4	21.7	24.4	23.7	22.5	23.2	22.5	22.8
04/07	20.2	23.35	25.4	24.1	22.6	23.7	22.5	22.8
05/07	21.0	22.8	24.5	25.1	21.9	24	22.5	23.1
06/07	22.0	22.5	24.2	22.9	22.1	23.5	22.5	22.2
07/07	22.2	22.15	25.4	22.4	22.4	23.7	22.5	23.4
08/07	21.8	22.7	25.1	24	23	22.6	22.5	23.7
09/07	20.8	21.15	24.4	24.7	23.7	22.7	22.5	23.9
10/07	20.5	21.85	24.4	22.9	24.4	22.3	22.5	24.5
11/07	21.6	22	24.8	23.8	24.4	22.1	22.5	22.5
12/07	21.5	22.2	24.2	24.6	24.7	22.9	22.5	22.6
13/07	21.3	22.85	24.8	24.8	24.6	21.9	22.5	22.9
14/07	22.3	24.25	19.7	25.8	22	23.2	22.5	23.2
15/07	21.8	20.15	20.9	22.4	20.3	24.7	22.5	22.8
16/07	21.8	22	22.1	21.9	21.8	24.6	22.5	21.3
17/07	21.0	22.1	20.5	21.9	24.1	24.6	22.5	22.6
18/07	21.0	22.45	20.6	24.4	23.3	23.3	22.5	22.8
19/07	23.7	23.5	19.4	24.7	22.2	23.6	22.5	23.4
20/07	22.6	22.5	18.8	25.4	24.1	24	22.5	24.5
21/07	23.8	21.25	19.9	24.5	23	24.7	22.5	23
22/07	22.9	22.35	19.6	23.7	20.8	24.5	22.5	23.3
23/07	22.5	21.3	21	22.8	20.6	25.1	22.5	23.7
24/07	21.9	22.15	16.8	21.3	20.3	24.5	22.5	22.4
25/07	20.3	22.9	19.9	21.1	19.7	24.7	22.5	21.3
26/07	20.5	22.5	22.2	22.8	19.7	25.2	22.5	22.8
27/07	19.9	22.4	21.8	21.1	20.5	24.4	22.5	23.4
28/07	21.9	23.95	18.4	23.7	22	23.2	22.5	23.3
29/07	23.0	21.4	18.2	24.3	24.4	21.2	22.5	22.6
30/07	22.7	23.35	21.4	22.8	21.3	22.5	22.5	21.9
31/07	20.7	22.95	22.1	22.3	20.5	22.7	22.5	22.5
01/08	20.8	22.4	20.7	22	22.2	22.4	22.1	23.6
02/08	21.8	22.9	19.6	19.8	23	23.9	22.1	24.4
03/08	21.5	22.6	20.3	20.5	23.9	24.2	22.1	25.2
04/08	19.8	22.5	21.4	20.1	23.5	23.8	22.1	22.3
05/08	20.0	22.35	22.4	19.7	21.8	23.9	22.1	22.8
06/08	20.7	21.45	23	22.3	21.6	24	22.1	23.9
07/08	20.5	21.7	23.3	19.8	22.5	23.6	22.1	24.2
08/08	19.7	20.15	24	20	22.3	24.4	22.1	20.9
09/08	20.0	20.85	23.3	21.3	23.4	23.6	22.1	19.2
10/08	20.1	23.1	22.5	22.7	23.4	19.8	22.1	21.2
11/08	20.2	22.85	22	22.9	24	22.7	22.1	23.3
12/08	21.4	22.45	22	22.3	23.3	24.1	22.1	22.5
13/08	22.1	22.5	22.6	22	22.8	22.4	22.1	21.9
14/08	21.0	23.25	23.7	21.7	23.4	21.5	22.1	20.7
15/08	20.7	22.05	23	22.4	23.4	21.5	22.1	21.9
16/08	21.9	22.3	21	22.9	24	21.2	22.1	22.8
17/08	21.3	22.5	22.3	22.7	23.6	21.5	22.1	22.7
18/08	21.2	21.95	24.2	21.5	22.8	23.3	22.1	23.1
19/08	21.5	22.65	22.4	20.15	23.3	23.8	22.1	23.5
20/08	21.9	22.95	23.3	23.1	23.3	22.9	22.1	24
21/08	21.6	23.85	22	23.3	24.9	22.8	22.1	24.1
22/08	21.4	22.3	22.2	22.4	22.9	23.4	22.1	23.4
23/08	21.3	21	22.6	23.3	23.7	23.6	22.1	23.2
24/08	20.5	24.35	19.7	23.8	22.7	22.9	22.1	23.5
25/08	19.9	22.25	23.9	23	24.1	22.9	22.1	22.5
26/08	21.5	24.45	22.7	23.2	24	23.6	22.1	21.7
27/08	20.2	23.3	21.9	23.3	24.1	22.5	22.1	20.6
28/08	21.0	24.05	23.8	20.7	24	22.8	22.1	20.8
29/08	20.6	21.7	21.6	22.4	23.3	21.5	22.1	22.9
30/08	20.1	23.95	20.9	21.35	23.6	21.8	22.1	23.5
31/08	18.7	22.85	20.9	23.3	23.5	22.1	22.1	24.4
01/09	19.3	23.25	21.6	23.9	23	22.4	21.7	20.7
02/09	20.1	20.4	21.2	22.8	22.8	21.6	22	20.7
03/09	20.9	20.25	21.8	21.8	21.3	23	21.8	20.7
04/09	18.8	21.15	22.1	21.2	22.2	22	22.8	20.7
05/09	18.4	20.4	23.1	21.4	20.8	21.4	19.9	20.7
06/09	19.9	19.75	22.9	21.4	21.6	21.8	20.9	20.7
07/09	19.4	21.75	21.6	22	22.9	22.2	21.8	20.7
08/09	18.8	21	21.4	22.1	23.3	22.5	21.2	20.7
09/09	19.7	21.5	19.7	22.1	22	22.1	21.3	20.7
10/09	19.3	21.3	20.9	21.7	22.1	22.4	20	20.7
11/09	17.9	20.1	20	22.8	21.2	22.1	20	20.7
12/09	17.9	22.95	20.4	22.7	23	21.4	21	20.7
13/09	19.7	20.25	20.4	21.6	22.6	20.7	20.7	20.7
14/09	19.9	22.5	20.2	21.6	21.6	20.9	19.8	20.7
15/09	20.9	19.85	20.8	20.7	21.3	20.7	20.8	20.7
16/09	19.8	20.3	21.2	19.7	19.9	20.8	21.5	20.7
17/09	18.7	18.2	21.3	19.8	20.1	20.6	19.8	20.7
18/09	18.7	18.4	21.7	21	21.5	20.3	19.5	20.7
19/09	16.6	17.9	21.8	21.3	21.3	21.1	19.8	20.7
20/09	16.9	17.7	22	20.6	21.4	21.3	19.6	20.7
21/09	16.7	17.65	21.6	18.4	22	20.1	19.1	20.7
22/09	16.0	17.85	20.7	19.6	21.4	21.4	18.7	20.7
23/09	16.7	18.1	19.9	18.9	20.8	22.9	18.7	20.7
24/09	16.2	17.65	19.3	18.6	20.4	20.3	18.7	20.7
25/09	16.4	17.9	20.5	20.5	21.4	20.1	19.3	20.7
26/09	16.9	16.7	22.1	20.5	19.9	19.1	19.5	20.7
27/09	16.3	17.2	20.2	20.7	20	19.5	19.8	20.7
28/09	16.2	17.05	19.5	19.5	19.5	19.7	19.8	20.7
29/09	15.9	18	18.8	18.8	19.7	20.1	18	20.7
30/09	16.5	17.2	18.6	18.8	20.6	20	15.8	20.7

01/10	17 2	18 5	18 8	17 10	19 8	19 7	17 7	17 1
02/10	16 0	16 9	18 8	17 10	19 4	19 7	17 5	17 1
03/10	15 0	17 8	19	17 10	19	19 8	18 5	17 1
04/10	14 9	16 95	17 5	17 10	18 3	20 3	19 7	17 1
05/10	15 1	17 05	17 9	17 10	18 4	18 7	17 6	17 1
06/10	14 5	16 15	18 6	17 10	17 6	18 3	19 1	17 1
07/10	16 7	16 45	18 2	17 10	18 7	18 6	20 2	17 1
08/10	16 1	17 05	18 6	17 10	18 5	18 1	16 5	17 1
09/10	15 3	15 95	18	17 10	19 2	18 4	16 2	17 1
10/10	14 1	15 45	17 8	17 10	18	18 1	17 9	17 1
11/10	14 8	16 3	17 1	17 10	17 4	18 2	18 2	17 1
12/10	14 3	18 3	16 8	17 10	16 6	17 7	17 6	17 1
13/10	14 0	18 05	16 7	17 10	16	17 6	16 7	17 1
14/10	13 7	15 85	16 6	17 10	17	17 3	16 4	17 1
15/10	15 5	16 8	16 7	17 10	17 3	17 9	16 6	17 1
16/10	15 5	15 95	17 1	17 10	18 3	18 4	16 1	17 1
17/10	15 8	16 7	17 4	17 10	17 3	18	15 5	17 1
18/10	16 1	14 65	16 8	17 10	16 6	17 1	15 9	17 1
19/10	15 7	16 85	16 1	17 10	15 6	16	15 2	17 1
20/10	14 0	15 7	16 3	17 10	15.5	16 5	15 2	17 1
21/10	14 0	15 55	16 5	17 10	15	17 8	15	17 1
22/10	14 1	16 65	16 5	17 10	15 8	18 1	15 6	17 1
23/10	14 0	17 3	16	17 10	16 2	16 7	16 2	17 1
24/10	14 8	16 35	15 3	17 10	16	16 5	15 5	17 1
25/10	13 6	16 55	15 1	17 10	16 3	15 9	14 9	17 1
26/10	14 2	17 3	15 5	17 10	15 8	15 7	15 3	17 1
27/10	14 0	17 6	15 3	17 10	15 8	15 3	15 5	17 1
28/10	13 7	18 2	14 6	17 10	16 4	15	15 5	17 1
29/10	12 8	15 3	14 7	17 10	16 8	14 6	15.1	17 1
30/10	12 8	14 2	14 4	17 10	15 4	14 9	14.4	17 1
31/10	12 7	14 15	13 8	17 10	14 8	14 8	14 4	17 1
01/11	12 4	16 8	14 3	15 1	15 3	14 4	14 4	14 6
2/11	12 9	15 75	14 6	13 9	15 5	14 6	15	14 6
03/11	15 1	13 95	15 2	13 45	16 3	15 4	14 6	14 6
04/11	16 7	13 6	14 8	13 55	15 1	14 8	13 6	14 6
05/11	15 7	12 95	14 2	13 1	14 4	14 9	14 3	14 6
06/11	15 1	13 4	13 7	13 9	14 3	14 4	15 1	14 6
07/11	15 1	14 1	13 1	14 05	17 9	12 6	15 3	14 6
08/11	15 8	12 65	13 2	13 6	14 2	12.5	15 9	14 6
09/11	16 6	16 8	13 1	13 8	14 9	12.8	16.2	14 6
10/11	14 6	14 05	13 5	14 55	14 4	13 5	15 4	14 6
11/11	13 1	12 9	13 8	15 1	15 5	13 2	14 7	14 6
12/11	14 1	11 75	13 8	15 45	14 6	11 9	17 3	14 6
13/11	15 6	11 4	15 2 ·	15 35	14 4	11 3	16 4	14 6
14/11	16 0	10 7	16 3	13 85	12.5	11 4	16 9	14 6
15/11	17 0	10 35	13 8	14 6	12.8	12 6	16 7	14 6
16/11	14 6	9 9	12 2	14 35	12 9	12.9	15 4	14 6
17/11	15 2	10 4	11 8	14 7	12 4	12.8	13.8	14 6
18/11	15 5	10 8	11 9	14 15	11 9	12.4	13.2	14 6
19/11	15 6	10 8	12 1	13 95	12 5	12 5	12.7	14 6
20/11	13 8	10 75	13 1	14	12 7	12.7	12.4	14 6
21/11	13 4	11 25	11 8	13 65	12.1	13 4	11 7	14 6
22/11	15 5	10 9	11 5	13 2	12.2	13 8	12 8	14 6
23/11	14 3	10 35	12	13.2	12	13 6	11 9	14 6
24/11	13 7	10 95	13 1	13 4	12 9	12.5	12 6	14 6
25/11	13 8	12 1	13 3	14 2	14 7	13.1	14 2	14 6
26/11	13 6	11 15	12 3	13 4	14 3	12.8	15 8	14 6
27/11	12 9	11 85	11 6	11 5	14 4	11 5	15	14 6
28/11	13 3	10 8	12 3	11 95	14 2	10.7	13 8	14 6
29/11	14 0	11 5	12 5	12 4	13 3	12.4	15 3	14 6
30/11	15 5	11 65	12.2	13 3	12.2	14 3	16 1	14 6
01/12	16 3	12 45	12 6	12.2	12.2	15 5	15 4	12 1
02/12	17 5	12 1	11 5	12 1	12.5	16 2	15 5	12 7
03/12	16 8	11 5	9 8	12 7	13	16 3	16 7	13.2
04/12	15 1	12 3	9 8	13 8	13.2	16.4	17 5	13
05/12	14 1	13 8	10 4	13.95	12 6	16 2	16 9	14
06/12	12 1	14 4	12.2	15 1	12.9	17 6	16 3	14 1
07/12	15 9	15 05	14 4	16 1	12 1	17.2	15 6	13 7
08/12	14 4	15 45	13 5	16 4	12.2	16 1	15.2	14 3
09/12	15 0	12 5	14 1	14 9	13 3	16 2	16 4	13.7
10/12	14 5	11 2	13.5	13 55	15.3	16.1	15.7	12 1
11/12	14.2	11	11 5	14 1	14.5	14.2	14.2	12
12/12	14 1	12	11 5	15 75	14	14.3	14	10
13/12	14 3	11 95	11.5	16 4	12.4	14 4	14.3	12
14/12	14 8	11 45	12.4	15.1	12.2	14 5	15.3	13.4
15/12	14 0	9.5	13.3	15.6	11.9	15.1	15.8	14.2
16/12	14 4	9.25	13 4	14.2	11.8	14.5	16.3	13.2
17/12	14 9	11 4	13 4	12 35	11.1	13.4	16	12.7
18/12	13 5	13 5	13.2	15 7	10.9	14.3	15.6	12.1
19/12	13 5	14 15	15 4	14.3	11.5	15	15.6	10 6
20/12	14 9	15 6	15.3	15.8	12.5	15.4	15.5	10 6
21/12	14 0	14 75	13 7	14 05	12.3	15.6	15.5	12 5
22/12	14 0	14 75	13 1	13.4	11.9	15.8	15.8	14 5
23/12	14 0	14 85	13 8	12 6	11 4	14.9	16	15 5
24/12	13.2	15 65	13	12.05	10 8	14 9	14	16
25/12	12 0	15 45	14 2	12 3	10 5	14.7	15	15 5
26/12	11 2	14 45	14 1	13 05	12.2	15.9	15.2	14 8
27/12	11 7	12.65	14 6	13 05	12.2	15.3	15 9	13
28/12	11 9	14 55	13.3	12 9	10 6	14 1	16 5	13 3
29/12	10 3	16 35	9.9	13 25	10 3	13.8	16.8	12.2
30/12	12.2	16 2	12	12.8	12.4	13.5	16.8	11 4
31/12	12.2	16 2	14.1	11 45	13	15	17	11.1

WIND SPEED m/s

jan	1986	1987	1988	1989	1990	1991	1992	1993
1	18	18	15	19	15	13	27	21
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4	18	20	12	22	20	16	32	15
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6	18	18	14	23	18	2.8	21	17
7	18	20	14	26	15	29	27	13
8	18	20	16	26	17	21	25	15
9	18	18	17	20	16	18	13	15
10	18	18	13	20	22	25	2.7	17
11	18	20	13	32	15	22	22	16
12	18	25	15	22	19	20	26	14
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15	18	21	14	19	19	18	29	17
16	18	20	07	27	19	14	26	16
17	18	20	10	36	27	14	18	11
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19	18	23	12	25	19	12	10	27
20	18	18	15	21	17	15	12	13
21	18	18	11	27	1.7	19	2.4	2.5
22	18	15	12	24	19	16	23	17
23	18	18	09	24	2.3	15	2.0	19
24	18	18	16	19	26	2.3	17	15
25	18	18	15	2.1	18	09	22	16
26	18	19	13	24	16	18	2.1	18
27	18	19	12	22	15	2.6	12	10
28	18	26	17	24	2.0	15	2.1	12
29	18	23	16	25	2.4	26	27	2.0
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31	18	22	21	25	22	16	16	25
feb								
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6	20	20	16	26	24	17	17	20
7	18	19	20	29	13	14	2.1	22
8	17	18	17	27	18	20	19	14
9	18	18	15	30	18	2.1	15	22
10	17	28	19	2.1	20	25	24	21
11	18	26	11	2.7	23	22	26	23
12	24	22	14	25	16	10	21	2.1
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14	23	20	14	32	14	14	14	20
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16	20	16	12	25	1.7	11	16	19
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26	18	21	25	20	22	14	28	18
27	17	30	24	22	22	17	20	12
28	16	20	16	16	26	22	24	22
29			15				24	
mar								
1	21	14	14	15	24	17	22	15
2	17	16	14	18	35	18	16	18
3	15	2.1	18	1.8	15	24	34	15
4	17	26	17	2.0	16	21	22	18
5	13	22	16	16	22	15	25	23
6	13	2.0	1.0	18	2.0	18	19	25
7	24	2.0	11	1.5	3.1	33	26	17
8	15	28	11	17	26	2.0	36	16
9	16	26	15	16	18	25	26	2.0
10	14	17	19	22	1.3	18	27	2.1
11	12	2.1	12	1.5	14	2.0	29	23
12	15	26	18	19	14	1.9	1.9	18
13	16	42	14	2.5	16	16	24	15
14	17	38	12	22	2.0	1.1	2.7	16
15	16	24	2.0	1.9	1.9	1.2	2.0	14
16	15	26	14	19	2.1	11	34	26
17	19	2.1	16	2.7	1.2	11	26	16
18	2.7	2.0	16	2.8	1.7	18	13	30
19	2.1	19	16	19	18	13	35	22
20	2.3	24	14	1.7	3.1	2.0	19	2.0
21	18	1.8	1.0	1.7	2.1	1.6	26	2.0
22	2.0	18	1.4	1.9	2.4	2.1	2.0	2.1
23	2.1	2.3	20	2.3	2.7	2.0	2.9	18
24	1.7	2.4	1.4	2.6	3.4	3.5	1.9	26
25	1.5	2.0	1.2	1.8	2.4	13	26	23
26	2.2	2.4	13	16	1.8	2.1	2.5	2.0
27	2.7	2.7	13	1.5	3.8	2.7	1.9	23
28	19	1.9	13	2.0	2.6	1.7	17	22
29	17	41	1.2	2.4	3.0	2.6	27	22
30	2.1	38	13	1.8	3.1	14	34	31
31	1.8	2.8	12	22	1.2	17	23	23

apr								
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6	11	31	23	24	23	21	19	26
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20	18	30	17	13	2.2	20	21	15
21	20	27	20	20	2.5	17	15	16
22	17	29	32	18	17	49	20	29
23	15	26	17	15	2.4	22	27	20
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25	17	22	13	18	20	15	26	19
26	24	23	12	22	2.7	34	19	14
27	21	22	13	22	21	21	19	18
28	19	24	11	26	18	20	23	17
29	18	21	12	2.1	2.7	16	2.5	10
30	14	22	13	21	16	17	19	17
may								
1	14	24	18	19	17	15	19	14
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13	18	29	11	35	2.2	13	19	33
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16	20	31	12	19	17	15	19	27
17	19	32	10	11	14	2.3	19	2.4
18	18	31	10	2.2	14	2.2	19	11
19	17	28	12	28	2.0	18	19	17
20	27	28	11	19	12	18	19	16
21	20	30	10	19	2.3	18	19	13
22	25	23	12	19	15	2.2	19	13
23	20	13	14	19	19	16	19	18
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26	19	26	10	19	20	20	19	15
27	18	27	11	13	2.4	17	19	17
28	19	24	27	19	13	23	19	16
29	18	25	14	19	2.6	21	19	26
30	24	23	15	19	3.5	18	19	12
31	23	25	17	19	19	15	19	20
jun								
1	21	2.2	16	2.5	25	21	23	17
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3	19	30	15	3.5	1.8	24	2.3	1.8
4	22	22	14	38	14	22	2.3	2.1
5	20	16	19	3.2	2.1	23	2.3	2.5
6	20	22	15	44	17	2.3	2.3	18
7	24	13	12	14	10	2.2	2.3	15
8	20	27	2.2	3.2	18	2.1	2.3	16
9	21	22	22	32	2.2	19	2.3	2.2
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11	22	3.5	22	2.4	19	40	2.3	2.1
12	26	46	20	41	2.2	30	2.3	19
13	26	2.7	18	17	2.5	32	2.3	1.7
14	2.6	40	2.4	2.6	2.8	2.3	2.3	1.7
15	2.8	2.2	32	2.1	2.0	33	2.3	2.1
16	2.2	19	26	2.1	2.2	20	2.3	2.8
17	19	2.4	1.7	2.5	1.9	2.4	2.3	2.3
18	2.0	2.2	19	18	19	2.6	2.3	20
19	2.1	2.2	3.0	2.3	3.8	28	2.3	2.4
20	19	16	1.9	3.0	2.2	3.8	2.3	2.3
21	3.0	3.2	18	2.4	2.6	32	2.3	2.2
22	18	2.7	18	44	2.3	18	2.3	1.4
23	2.1	30	2.5	36	2.9	2.0	2.3	15
24	18	3.2	3.1	2.1	3.3	26	2.3	2.1
25	16	2.7	2.2	3.2	3.3	3.4	2.3	2.0
26	24	24	15	3.1	2.7	31	2.3	31
27	21	30	19	27	2.8	24	2.3	28
28	19	27	20	25	1.9	3.4	2.3	2.5
29	2.1	27	16	2.6	2.2	24	2.3	18
30	2.1	2.7	2.2	1.5	19	2.4	2.3	17

jul									
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	13	20	24	13	12	15	25	24	29
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	18	24	22	12	18	25	15	24	28
	19	30	24	48	16	31	18	24	16
	20	21	31	36	21	33	31	24	15
	21	22	23	12	09	29	17	2.4	33
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	30	25	26	26	27	38	2.9	24	29
	31	20	24	38	29	29	49	24	20
aug									
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	11	15	27	29	21	25	31	23	20
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	13	18	21	15	38	28	2.8	23	26
	14	17	27	2.0	32	26	35	2.3	39
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	19	20	33	20	3.4	30	12	23	16
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	21	23	23	15	29	2.1	12	23	14
	22	22	25	14	29	21	20	23	19
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	27	17	28	41	23	27	21	23	26
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	30	19	19	36	19	23	27	23	19
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sep									
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	2	17	20	22	23	37	17	19	17
	3	12	19	18	14	22	30	17	17
	4	2.0	21	24	2.3	22	25	23	25
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	7	18	23	19	20	16	28	16	2.0
	8	18	20	2.4	2.1	15	2.3	22	19
	9	18	18	1.4	2.0	12	16	13	18
	10	19	25	19	16	2.0	2.2	11	1.7
	11	15	19	18	2.1	2.6	18	2.2	14
	12	14	24	2.3	16	3.1	18	2.3	16
	13	2.1	28	2.2	1.5	1.1	2.2	16	1.9
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	15	18	23	2.0	18	20	15	19	18
	16	17	27	2.4	1.8	2.0	19	15	16
	17	18	2.2	1.2	13	2.2	16	1.3	2.1
	18	2.2	30	2.4	2.0	18	1.7	10	24
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	21	1.7	26	14	2.2	19	2.3	16	17
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	28	19	18	2.1	2.9	19	15	17	15
	29	15	29	1.0	23	19	20	19	14
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oct									
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	11	18	18	17	18	20	15	19	16
	12	18	18	24	18	18	17	2.2	14
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	15	15	21	22	18	16	14	20	15
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	31	14	22	29	18	17	15	20	14
nov									
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	2	12	17	19	17	17	18	18	15
	3	12	19	29	17	18	18	18	14
	4	12	21	21	17	17	18	15	12
	5	14	19	15	17	16	18	20	17
	6	12	18	15	17	20	19	18	20
	7	14	18	16	17	11	16	18	17
	8	13	25	18	17	16	16	20	18
	9	14	21	23	17	15	24	2.2	14
	10	15	20	19	17	14	15	2.4	17
	11	18	20	23	17	16	17	14	16
	12	15	17	26	17	17	18	15	14
	13	13	17	25	17	19	17	14	14
	14	19	17	19	17	15	17	16	15
	15	20	19	13	17	16	13	14	15
	16	14	16	19	17	17	17	15	14
	17	14	18	19	17	2.2	19	16	21
	18	14	16	24	17	17	15	2.2	19
	19	14	18	18	17	16	13	14	16
	20	15	18	18	17	16	11	15	14
	21	16	17	20	17	15	16	1.9	16
	22	15	18	19	17	13	17	16	16
	23	14	16	30	17	16	16	15	16
	24	15	16	18	17	19	16	17	18
	25	15	16	25	17	17	1.7	21	16
	26	15	18	17	17	14	18	24	17
	27	16	18	22	17	20	25	16	20
	28	14	17	16	17	19	16	11	15
	29	12	16	18	17	16	15	14	20
	30	14	17	13	17	15	2.1	18	16
dec									
	1	13	17	19	18	16	19	15	19
	2	15	18	26	18	17	2.2	18	16
	3	16	17	17	18	18	12	17	13
	4	19	17	19	18	16	19	1.3	17
	5	24	14	17	18	17	33	11	17
	6	11	16	14	18	12	34	18	1.1
	7	14	16	2.1	18	14	13	2.0	17
	8	14	14	2.1	1.8	14	1.7	2.2	16
	9	13	18	19	18	19	2.8	17	18
	10	14	21	2.1	18	10	18	2.1	11
	11	15	15	13	18	2.2	2.3	1.3	17
	12	15	15	18	18	16	17	1.9	18
	13	15	16	2.0	18	2.4	15	16	1.3
	14	15	19	22	18	12	1.5	1.9	14
	15	17	18	18	18	15	14	1.7	18
	16	17	19	2.1	1.8	1.6	2.1	1.7	17
	17	1.4	2.0	2.1	1.8	14	2.2	15	1.8
	18	15	2.1	2.1	18	15	1.5	1.5	1.9
	19	13	17	2.6	1.8	15	2.0	1.9	17
	20	16	15	2.1	1.8	14	1.8	2.1	1.5
	21	15	18	15	1.8	17	1.6	2.4	13
	22	15	16	2.2	1.8	18	2.4	1.8	2.3
	23	15	15	2.4	1.8	16	1.9	2.3	16
	24	15	18	2.4	1.8	1.4	1.7	2.0	16
	25	15	17	31	18	1.9	1.7	2.5	2.0
	26	13	24	24	18	1.9	2.1	2.7	2.0
	27	12	18	31	18	15	2.1	2.0	19
	28	16	18	27	18	12	16	18	18
	29	14	18	23	18	12	1.6	2.4	1.2
	30	09	13	25	18	10	11	2.3	16
	31	15	26	2.0	18	19	2.7	2.0	23

Measured air humidity mb

jan	1986	1987	1988	1989	1990	1991	1992	1993
1	79	75	130	40	63	6.2	6.6	79
2	79	91	119	39	7.1	76	8.0	71
3	79	93	118	45	72	83	80	8.5
4	79	89	113	65	8.1	87	98	73
5	79	85	80	79	74	97	74	49
6	79	90	61	71	84	91	59	42
7	79	83	64	6.2	83	8.8	76	46
8	79	81	95	76	78	93	84	49
9	79	89	93	6.7	8.3	97	66	60
10	79	84	97	6.2	9.2	96	6.0	57
11	79	81	84	65	84	115	9.9	7.2
12	79	75	82	76	10.2	96	6.8	83
13	79	62	80	73	91	7.4	5.9	101
14	79	6.5	83	83	9.5	81	7.1	97
15	79	58	81	72	9.5	95	8.6	80
16	79	38	103	85	9.4	8.3	115	79
17	79	2.2	9.7	103	88	85	10.8	74
18	79	25	103	75	9.0	80	9.6	5.6
19	79	2.2	89	60	87	66	9.0	6.7
20	79	2.7	61	7.3	94	60	90	6.1
21	79	31	66	8.4	88	5.4	9.4	77
22	79	36	71	80	9.1	6.0	100	97
23	79	41	74	73	10.0	9.2	10.4	10.4
24	79	46	54	54	10.9	9.0	11.1	103
25	79	53	51	44	10.3	105	10.4	106
26	79	69	65	44	9.4	10.0	9.7	10.7
27	79	83	86	4.1	7.2	10.6	10.3	9.9
28	79	96	61	49	9.5	96	9.9	8.7
29	79	75	76	5.8	84	9.2	7.7	8.6
30	79	58	70	41	8.1	93	11.3	9.2
31	79	56	81	5.5	7.6	9.2	12.0	88
feb								
1	79	48	76	84	74	8.9	13.6	88
2	68	40	75	9.6	8.1	69	117	10.4
3	89	45	71	104	94	65	111	109
4	90	53	71	109	12.5	70	10.9	107
5	95	36	59	100	12.5	76	10.2	114
6	105	39	56	93	14.3	87	9.4	104
7	66	47	59	74	14.2	9.6	111	81
8	74	46	65	8.0	149	104	96	8.2
9	79	70	68	84	130	118	9.7	86
10	96	100	74	10.1	12.6	9.2	10.8	97
11	70	99	81	9.8	13.4	105	10.8	10.2
12	73	93	79	10.0	13.2	12.7	7.7	12.3
13	87	8.2	87	9.2	128	9.0	9.1	10.5
14	66	7.2	100	8.2	12.1	9.2	10.0	87
15	99	50	11.3	6.7	12.5	9.7	9.2	8.8
16	94	39	11.2	6.1	12.7	8.0	6.6	7.3
17	96	48	10.8	6.5	11.5	78	9.3	79
18	110	68	11.2	6.1	12.2	9.4	9.9	77
19	97	8.1	10.6	8.3	9.7	9.8	7.8	66
20	5.5	108	116	79	9.8	10.4	7.7	44
21	54	91	113	8.2	11.7	9.7	8.5	48
22	49	105	121	9.3	11.5	10.1	8.3	6.2
23	54	111	106	99	114	9.6	9.2	8.4
24	43	115	10.2	74	120	11.5	9.8	9.9
25	8.2	109	103	76	117	133	10.9	78
26	9.5	117	117	61	9.2	13.2	119	53
27	92	116	12.0	48	8.9	134	10.6	40
28	86	9.8	115	49	114	13.9	9.0	4.1
29			101				9.1	
mar								
1	76	11.1	104	10.7	14.1	12.2	10.9	3.7
2	120	11.0	10.7	10.7	11.5	13.7	12.3	3.6
3	11.5	11.0	104	10.7	10.1	13.9	11.4	3.6
4	11.5	118	10.1	10.7	6.5	11.8	8.5	45
5	117	10.3	8.2	107	6.1	13.0	9.6	5.7
6	106	12.3	7.7	10.7	8.5	13.3	10.2	7.2
7	10.3	12.7	7.7	10.7	10.8	15.2	10.2	9.0
8	10.2	11.6	6.3	10.7	10.0	14.4	11.7	10.2
9	9.8	12.0	75	10.7	6.0	13.8	11.9	10.7
10	90	11.3	10.1	10.7	6.0	15.0	10.1	10.5
11	11.5	12.0	8.8	10.7	8.3	14.0	8.5	9.8
12	11.0	11.5	8.3	10.7	9.0	12.1	8.5	11.3
13	11.7	11.0	9.5	10.7	8.0	12.8	9.4	10.3
14	114	10.2	9.3	10.7	8.0	12.0	8.7	8.3
15	111	7.5	9.6	10.7	7.0	11.9	10.2	9.7
16	10.8	8.8	9.9	10.7	8.0	12.7	12.0	11.1
17	9.5	10.8	7.3	10.7	7.6	10.8	10.3	10.7
18	87	10.6	5.8	10.7	9.0	10.4	11.2	11.5
19	12.2	10.7	8.2	10.7	12.0	11.9	14.6	10.7
20	11.9	9.9	9.6	10.7	11.0	12.0	15.0	8.3
21	6.3	105	10.5	10.7	11.8	14.0	13.8	9.3
22	84	10.8	10.2	10.7	12.1	13.8	13.7	9.0
23	7.6	10.8	8.2	10.7	12.3	13.7	12.6	8.5
24	8.5	12.4	3.9	10.7	11.1	12.8	12.5	8.7
25	86	11.9	5.2	10.7	11.3	12.6	11.5	9.7
26	88	12.4	7.2	10.7	10.0	115	11.6	9.3
27	70	12.9	9.1	10.7	10.6	11.2	11.2	11.4
28	8.2	13.2	6.7	10.7	12.5	12.7	10.6	12.7
29	6.2	12.6	5.8	10.7	10.4	14.4	12.0	12.1
30	8.7	12.6	5.3	10.7	11.2	13.7	13.2	12.5
31	10.2	12.6	4.6	10.7	11.0	14.3	11.6	11.9

apr									
	1	102	156	43	12.2	113	124	98	112
	2	94	125	5.5	121	121	130	96	126
	3	121	138	56	101	131	122	118	127
	4	116	134	66	95	142	127	144	123
	5	121	123	75	9.3	145	138	164	135
	6	110	132	76	112	131	135	151	135
	7	124	145	81	118	124	130	105	135
	8	121	153	76	119	12.6	118	81	138
	9	124	151	80	12.2	78	138	58	132
	10	130	159	86	12.2	69	137	49	137
	11	120	161	92	98	64	138	48	131
	12	104	155	105	11.5	68	130	51	131
	13	114	149	142	110	6.2	107	55	140
	14	110	153	119	110	56	84	63	137
	15	105	100	139	11.0	47	81	78	133
	16	107	77	142	99	76	89	95	128
	17	108	63	144	94	6.2	99	10.2	120
	18	114	76	146	86	64	118	110	116
	19	105	94	138	64	56	106	68	114
	20	113	93	15.2	12.3	59	126	81	118
	21	11.2	58	146	111	5.5	12.5	92	12.9
	22	108	50	139	114	54	71	94	126
	23	119	54	145	90	99	74	114	133
	24	12.5	53	127	129	12.8	75	12.2	125
	25	120	60	111	141	120	68	136	131
	26	130	71	9.5	9.9	12.4	58	153	117
	27	116	79	11.2	94	118	52	137	125
	28	87	74	117	10.2	12.7	6.0	114	126
	29	111	59	89	10.6	11.3	5.7	144	12.9
	30	9.2	96	81	10.6	9.7	61	14.4	12.0
may									
	1	12.7	80	64	3.3	8.9	66	10.3	117
	2	12.7	57	56	3.2	98	88	10.3	107
	3	121	73	63	34	110	86	10.3	128
	4	111	83	76	34	109	91	10.3	120
	5	12.5	55	89	24	115	80	10.3	118
	6	126	54	81	31	116	104	10.3	12.0
	7	126	88	54	36	108	129	10.3	13.2
	8	12.5	117	63	3.9	117	127	10.3	100
	9	104	13.3	56	34	84	12.3	10.3	98
	10	130	132	57	30	98	86	10.3	104
	11	136	111	91	52	12.8	63	10.3	104
	12	131	79	91	6.9	14.0	74	10.3	142
	13	136	82	79	6.8	14.3	112	10.3	150
	14	134	88	6.2	74	114	10.4	10.3	139
	15	134	80	8.9	87	107	101	10.3	132
	16	13.2	65	6.2	44	110	94	10.3	144
	17	68	5.5	61	5.0	9.6	11.3	10.3	137
	18	73	51	57	9.5	9.6	11.9	10.3	117
	19	80	50	51	11.6	8.3	9.6	10.3	102
	20	81	58	54	12.0	5.2	101	10.3	91
	21	84	8.5	6.2	7.3	5.2	102	10.3	85
	22	110	98	6.1	5.3	5.1	108	10.3	84
	23	50	13.2	5.2	6.3	51	104	10.3	91
	24	52	10.9	4.9	7.4	76	112	10.3	82
	25	106	87	51	9.4	75	114	10.3	74
	26	5.9	8.0	51	7.8	6.3	8.3	10.3	78
	27	48	85	47	6.6	7.6	5.9	10.3	8.2
	28	42	80	41	12.3	8.9	7.2	10.3	76
	29	85	8.6	40	8.4	10.2	83	10.3	8.3
	30	41	91	66	6.6	12.5	10.5	10.3	87
	31	3.8	94	6.3	8.3	13.8	7.0	10.3	12.1
jun									
	1.0	54	7.3	7.8	9.2	101	5.9	96	115
	2.0	72	66	71	9.0	71	6.1	96	102
	3.0	103	50	5.3	9.8	60	65	96	88
	4.0	5.0	54	5.5	88	5.0	6.1	96	97
	5.0	46	9.5	6.8	10.6	5.4	6.0	96	132
	6.0	3.8	96	57	14.0	4.9	62	96	113
	7.0	3.9	6.3	5.0	13.6	5.0	5.7	96	93
	8.0	49	67	6.0	12.9	47	72	96	81
	9.0	6.7	49	5.9	13.0	5.3	71	96	73
	10.0	6.8	40	8.3	12.8	6.3	7.8	96	10.9
	11.0	6.5	5.2	8.5	13.0	5.1	8.4	96	96
	12.0	5.3	78	6.2	13.0	5.9	12.1	96	71
	13.0	5.2	104	5.7	11.7	9.6	11.0	96	65
	14.0	44	12.0	8.9	10.4	10.1	9.3	96	8.7
	15.0	4.3	9.6	10.4	11.6	8.4	7.9	96	10.8
	16.0	4.8	8.4	10.1	11.6	6.6	8.6	96	10.1
	17.0	7.2	8.9	8.3	11.6	5.2	72	96	110
	18.0	91	8.6	7.9	5.8	5.4	6.6	96	8.0
	19.0	6.5	6.9	8.2	8.5	5.6	111	96	95
	20.0	7.7	9.3	5.4	10.7	5.8	116	96	9.0
	21.0	9.4	8.3	3.9	7.6	6.9	10.1	96	8.7
	22.0	8.7	79	3.9	78	8.4	8.8	96	8.9
	23.0	8.4	80	8.2	9.8	8.4	10.9	96	78
	24.0	8.0	84	8.7	9.7	8.8	113	96	10.2
	25.0	7.3	87	7.0	10.8	97	97	96	12.5
	26.0	9.0	97	6.3	9.0	10.5	92	96	10.8
	27.0	9.4	10.2	5.1	7.4	10.7	12.4	96	8.9
	28.0	7.8	12.9	7.2	7.3	9.1	145	96	10.7
	29.0	8.5	7.8	7.6	7.7	9.8	111	96	10.5
	30.0	8.5	6.3	7.8	8.0	10.4	10.7	96	8.1

		1986	1987	1988	1989	1990	1991	1992	1993
jul									
	10	64	65	86	65	82	90	119	71
	20	51	61	107	61	81	84	119	73
	30	40	84	82	63	88	12.9	119	61
	40	60	98	60	66	89	134	119	78
	50	75	97	81	71	85	110	119	96
	60	71	87	56	73	9.9	112	11.9	108
	70	76	109	78	95	89	123	119	104
	80	89	123	114	75	87	117	119	107
	90	98	107	109	73	84	12.7	119	96
	100	124	93	100	98	90	8.9	11.9	95
	110	100	94	88	108	98	87	11.9	102
	120	94	92	101	95	73	112	119	11.2
	130	72	105	88	97	71	118	11.9	12.9
	140	75	114	148	106	104	102	119	128
	150	78	102	139	134	117	9.7	11.9	12.2
	160	63	95	120	135	101	10.2	119	113
	170	48	80	130	133	92	90	119	99
	180	53	90	132	119	88	9.8	119	10.8
	190	68	100	136	10.6	108	97	119	10.7
	200	73	107	130	118	10.5	9.7	119	10.9
	210	66	94	11.3	12.0	10.6	10.4	119	12.5
	220	127	84	11.2	144	12.0	9.5	119	117
	230	137	64	115	140	13.2	114	11.9	96
	240	132	71	147	11.9	145	12.1	11.9	10.8
	250	123	113	145	13.0	140	114	119	115
	260	129	109	151	11.2	13.3	10.5	119	105
	270	128	103	154	10.8	13.1	10.5	119	108
	280	130	114	158	9.0	12.2	12.1	11.9	10.7
	290	71	99	145	87	96	13.8	119	12.8
	300	107	98	144	91	12.4	12.1	119	12.4
	310	136	99	137	131	13.5	10.8	119	10.7
aug									
	10	126	88	140	122	12.0	110	134	94
	20	131	95	152	141	10.2	96	134	72
	30	138	123	130	140	88	8.2	134	70
	40	140	128	127	139	93	75	134	117
	50	144	130	124	115	121	95	13.4	11.7
	60	128	129	113	118	12.5	110	134	84
	70	128	146	107	12.8	113	10.2	134	74
	80	120	116	96	117	109	9.5	13.4	135
	90	119	120	114	114	8.3	142	134	147
	100	114	134	128	107	6.8	151	134	148
	110	117	154	122	119	81	13.3	134	140
	120	126	154	12.2	13.4	9.0	13.7	13.4	125
	130	126	147	91	14.2	100	146	134	12.7
	140	111	150	100	11.9	90	15.5	13.4	12.5
	150	99	155	126	11.1	89	13.9	13.4	12.0
	160	100	149	144	8.9	9.9	13.8	13.4	10.8
	170	126	103	134	10.5	10.7	13.0	13.4	95
	18.0	130	124	120	12.1	8.7	10.7	13.4	87
	190	100	118	12.9	118	9.0	9.0	13.4	78
	200	132	138	85	11.6	10.3	11.7	13.4	7.2
	210	103	141	94	111	9.4	119	13.4	69
	220	125	160	81	137	89	10.0	13.4	88
	230	124	119	105	140	83	98	13.4	8.3
	240	149	70	133	10.8	7.0	126	13.4	10.6
	250	126	96	111	90	5.6	12.0	134	12.7
	260	133	101	113	10.3	49	88	13.4	12.0
	270	119	93	129	6.9	8.1	6.8	13.4	11.7
	280	125	93	126	15.1	11.3	7.7	13.4	113
	290	120	89	139	132	12.8	10.7	13.4	116
	300	66	121	130	10.2	12.2	12.2	13.4	9.4
	310	97	100	130	73	11.2	11.1	13.4	8.4
sep									
	10	85	100	13.6	154	10.0	9.7	12.9	7.1
	20	6.5	8.1	13.4	15.2	10.0	11.7	10.8	6.8
	30	42	68	114	12.4	9.1	13.3	11.7	6.7
	4.0	67	74	9.2	8.2	11.7	10.3	14.2	10.0
	50	70	7.2	75	8.9	12.8	9.8	16.6	93
	6.0	111	97	5.9	11.1	10.1	9.4	16.2	6.6
	7.0	10.7	140	5.8	9.8	8.3	11.1	10.4	6.1
	80	6.1	119	6.5	9.9	5.9	12.1	9.9	66
	90	6.4	12.5	143	9.2	6.8	11.0	12.1	6.9
	10.0	7.1	12.0	11.4	8.1	9.9	10.6	11.6	7.1
	11.0	9.7	8.6	10.1	8.3	9.3	9.1	11.5	6.2
	12.0	68	9.0	10.0	9.8	8.9	8.2	9.9	7.0
	13.0	68	8.3	7.2	9.8	5.4	7.7	8.9	6.4
	140	119	90	10.6	9.2	4.6	8.0	8.3	5.6
	15.0	12.5	9.9	12.9	8.0	5.1	10.1	9.5	5.4
	16.0	116	10.3	117	6.6	5.3	10.0	10.8	5.5
	17.0	10.8	6.8	10.9	7.9	6.6	10.3	8.6	5.7
	18.0	5.8	9.3	9.1	7.7	8.3	9.6	8.9	8.5
	19.0	49	10.7	7.1	7.3	6.5	10.3	9.5	10.3
	20.0	5.9	7.1	7.8	7.0	8.4	11.3	8.8	8.4
	21.0	5.6	8.4	7.3	6.0	8.6	9.5	7.8	7.9
	22.0	5.4	88	7.0	6.5	8.1	15.0	8.5	6.9
	23.0	5.4	96	5.4	5.8	6.4	10.3	9.1	6.5
	240	5.5	88	5.5	5.9	7.8	5.6	8.6	75
	25.0	66	9.0	70	8.2	7.0	4.9	8.7	7.6
	26.0	5.3	88	6.0	12.2	7.5	5.4	8.3	7.0
	27.0	47	9.1	6.5	10.0	6.3	5.1	7.8	5.6
	28.0	45	102	5.2	8.3	6.9	5.6	8.4	5.9
	29.0	4.2	10.2	5.1	7.1	7.6	5.0	6.8	6.2
	30.0	4.3	11.4	5.6	6.4	8.9	5.0	10.0	8.2

oct	10	42	152	62	74	67	54	85	74
	20	47	142	60	78	58	66	87	58
	30	43	98	49	78	64	80	89	55
	40	44	60	49	78	55	78	73	66
	50	47	63	67	78	51	75	111	68
	60	42	67	88	78	60	60	126	68
	70	38	68	77	78	63	78	12.3	63
	80	63	77	73	78	69	77	142	66
	90	47	72	60	7.8	5.5	61	147	63
	100	39	69	54	78	43	63	125	71
	110	39	73	55	78	49	63	115	64
	120	37	84	53	78	3.8	6.6	10.5	74
	130	40	69	56	78	46	59	100	72
	140	32	80	55	78	5.2	58	101	6.6
	150	41	81	53	78	78	73	8.8	63
	160	45	94	57	7.8	85	70	78	7.1
	170	44	69	6.2	78	67	68	6.1	70
	180	49	60	84	78	67	5.6	6.6	103
	190	49	63	70	78	63	6.1	65	12.8
	200	37	57	67	7.8	5.7	87	5.7	77
	210	31	54	6.3	78	73	108	39	6.5
	220	33	47	85	78	5.7	77	4.5	78
	230	38	62	74	78	61	6.3	5.1	106
	240	42	62	74	78	6.1	56	49	112
	250	48	65	77	78	5.5	5.6	5.7	6.6
	260	30	78	6.9	7.8	5.4	72	65	6.2
	270	49	83	64	78	5.5	57	65	62
	280	51	96	56	7.8	5.6	48	63	76
	290	37	92	50	78	5.7	48	5.5	9.2
	300	37	52	4.5	7.8	47	5.0	6.0	91
	310	35	77	46	78	6.1	68	6.3	102
nov	10	30	114	49	78	5.3	6.8	6.4	79
	20	31	101	72	48	60	59	61	66
	30	71	92	84	3.2	61	51	6.2	61
	40	95	83	67	31	5.6	46	75	59
	50	66	87	64	34	61	50	82	51
	60	50	82	57	33	55	45	8.3	66
	70	52	64	56	41	51	41	78	88
	80	88	47	52	38	54	40	83	85
	90	95	76	44	3.3	5.5	45	84	7.5
	100	57	77	46	36	57	6.1	8.7	69
	110	39	59	47	56	6.3	62	95	58
	120	42	47	49	58	5.9	5.7	8.9	63
	130	70	36	66	54	5.2	5.4	86	49
	140	94	2.9	81	4.5	57	48	10.9	58
	150	75	34	80	3.5	6.5	5.2	9.6	68
	160	7.5	41	76	3.8	7.3	57	6.7	71
	170	61	48	7.3	3.9	7.3	5.7	5.9	70
	180	42	49	56	3.2	58	5.4	74	6.1
	190	39	50	50	2.9	49	56	76	6.2
	200	38	50	54	2.7	46	5.6	6.4	63
	210	44	54	49	2.9	44	5.8	45	57
	220	80	56	49	2.7	4.5	65	49	46
	230	46	57	49	2.6	5.4	67	4.7	45
	240	50	69	48	13	77	8.2	51	5.0
	250	45	73	48	2.6	76	94	67	58
	260	50	70	45	28	6.5	84	8.1	58
	270	55	64	43	2.6	63	5.9	8.7	5.4
	280	68	60	47	2.8	6.7	44	9.5	4.8
	290	45	53	45	2.5	7.3	3.0	110	42
	300	51	45	4.5	2.6	7.1	43	9.7	47
dec		00	5360	536.0	40				
	10	76	45	50	34	7.1	66	9.0	62
	20	87	49	4.5	3.2	7.2	7.4	9.2	4.8
	30	97	59	5.4	3.4	7.0	10.3	10.4	4.3
	40	84	6.2	5.1	4.6	6.5	12.5	10.5	41
	50	93	60	5.3	4.9	5.7	12.5	8.8	4.0
	60	12.0	84	4.7	7.2	6.1	12.6	9.3	4.5
	70	10.5	75	6.1	7.9	6.6	9.3	0.0	4.2
	80	91	6.3	6.6	9.0	7.6	9.4	8.4	4.3
	90	89	74	6.3	9.3	74	9.3	9.5	5.1
	100	86	6.7	6.1	10.2	6.6	6.8	10.3	46
	110	7.5	50	6.5	10.3	5.9	3.8	9.0	5.2
	12.0	83	3.9	6.5	8.9	5.9	4.0	7.8	5.1
	13.0	84	41	6.7	9.1	5.7	4.9	6.9	4.4
	140	86	3.7	6.1	8.9	6.4	70	5.9	5.1
	15.0	7.7	3.9	5.4	9.2	6.0	8.2	6.9	5.3
	160	8.2	5.1	4.8	9.6	5.4	7.8	7.0	5.6
	170	8.0	6.6	4.5	9.2	5.1	7.7	7.4	6.3
	18.0	70	6.3	4.9	11.6	5.3	9.7	6.8	6.6
	19.0	6.2	7.3	5.9	11.4	4.9	9.2	8.6	5.2
	20.0	5.1	7.3	6.0	10.6	5.2	9.1	9.1	4.4
	21.0	6.4	7.0	4.3	8.3	5.1	9.7	8.0	5.7
	22.0	6.4	6.8	5.3	8.3	5.7	9.6	10.0	6.0
	23.0	6.4	69	5.6	8.0	5.3	9.6	11.8	6.8
	240	7.6	7.8	6.2	7.0	5.4	8.6	11.4	7.8
	250	4.1	75	5.2	5.6	5.2	6.9	10.9	7.9
	260	40	6.7	46	6.5	5.4	6.5	11.4	9.0
	27.0	3.0	77	5.7	6.5	5.6	5.5	11.2	8.3
	28.0	2.4	7.2	7.7	7.9	56	49	10.4	6.2
	29.0	2.2	11.5	7.3	6.9	5.8	6.0	10.4	4.8
	300	2.4	11.9	5.9	6.2	5.4	6.4	10.0	3.2

RELATIVE HUMIDITY % RH

	1986	1987	1988	1989	1990	1991	1992	1993
jan								
1	47	40	84	31	45	42	47	47
2	47	50	79	29	48	41	47	42
3	47	52	76	32	43	48	47	48
4	47	53	69	41	46	49	47	42
5	47	48	53	53	45	55	47	32
6	47	43	40	50	50	56	47	27
7	47	49	41	47	53	59	47	31
8	47	37	56	51	49	58	47	33
9	47	48	57	47	49	59	47	38
10	47	50	64	43	53	59	47	39
11	47	51	54	44	54	60	47	49
12	47	40	47	51	65	55	47	48
13	47	36	47	47	57	41	47	58
14	47	35	53	53	54	44	47	68
15	47	40	51	49	51	53	47	70
16	47	31	57	54	55	45	47	60
17	47	21	54	63	52	45	47	52
18	47	19	58	54	58	46	47	41
19	47	20	59	48	64	37	47	44
20	47	20	48	48	68	37	47	43
21	47	18	43	59	60	31	47	49
22	47	18	47	57	58	33	47	60
23	47	18	48	51	57	49	47	61
24	47	18	37	40	59	48	47	62
25	47	17	30	38	55	55	47	71
26	47	22	36	35	54	55	47	74
27	47	27	50	31	45	56	47	67
28	47	49	35	34	43	64	47	60
29	47	44	48	37	48	56	47	56
30	47	40	43	29	58	54	47	52
31	47	42	45	34	53	53	47	49
feb								
1	47	30	42	47	46	49	73	46
2	45	21	39	52	44	39	65	54
3	57	17	36	57	48	39	58	57
4	55	19	42	63	49	41	58	58
5	52	19	38	64	63	40	60	61
6	54	18	36	59	46	43	54	70
7	36	19	34	48	44	61	60	72
8	39	16	35	48	48	56	56	58
9	39	16	36	50	49	65	56	57
10	44	29	42	58	63	55	60	62
11	35	32	47	57	81	60	62	67
12	40	36	44	57	87	73	52	81
13	45	27	46	52	68	55	55	61
14	39	27	53	49	65	54	56	49
15	52	19	56	41	63	69	55	49
16	52	17	57	37	63	59	40	38
17	53	17	55	39	59	51	49	45
18	62	19	61	36	65	53	54	42
19	57	18	53	44	51	54	45	37
20	36	34	65	46	51	57	44	24
21	32	40	67	46	65	56	47	26
22	29	39	69	48	58	54	43	31
23	32	49	60	57	63	51	42	42
24	27	45	58	47	63	58	43	55
25	45	58	58	42	61	69	50	51
26	49	58	62	46	50	72	56	34
27	51	59	69	29	48	66	53	29
28	48	52	67	31	59	66	49	29
29			53				49	
mar								
1	39	53	49	51	58	61	55	26
2	75	58	50	51	66	65	64	25
3	90	53	51	51	54	68	62	25
4	70	61	48	51	39	58	52	28
5	62	48	39	51	36	61	53	33
6	55	49	35	51	46	63	55	36
7	55	58	36	51	52	79	52	43
8	51	52	27	51	44	78	56	46
9	51	50	35	51	28	72	54	50
10	40	52	44	51	30	73	46	47
11	51	50	41	51	44	69	41	43
12	48	51	38	51	44	64	42	51
13	51	48	45	51	39	62	49	49
14	48	44	44	51	41	57	45	40
15	47	40	44	51	33	62	47	47
16	46	36	49	51	43	67	51	52
17	41	49	42	51	37	58	48	52
18	42	52	30	51	42	50	50	52
19	53	49	40	51	53	53	70	49
20	51	48	50	51	48	51	72	43
21	30	50	49	51	56	60	72	48
22	40	52	47	51	61	55	65	41
23	36	50	38	51	59	52	56	40
24	39	61	19	51	53	59	53	40
25	37	58	27	51	51	63	50	45
26	39	48	33	51	46	60	51	43
27	28	47	41	51	54	56	51	56
28	38	54	30	51	70	65	51	72
29	28	61	26	51	58	74	53	69
30	36	47	23	51	56	74	67	70
31	39	51	22	51	52	84	58	65

apr								
1	43	50	20	58	52	69	47	53
2	44	46	24	54	60	68	45	67
3	52	50	25	51	71	59	56	73
4	58	52	26	50	73	53	66	67
5	62	33	32	50	76	57	74	77
6	59	56	37	66	65	57	74	82
7	61	54	40	88	61	51	58	70
8	66	77	34	88	58	47	43	69
9	64	58	36	83	49	54	30	66
10	78	66	43	67	38	57	25	68
11	65	61	49	53	31	60	24	69
12	54	65	54	56	32	53	25	71
13	53	57	79	51	30	45	25	82
14	63	52	58	51	28	37	30	83
15	54	45	69	49	23	37	36	93
16	54	43	74	47	37	37	42	81
17	54	30	78	46	31	42	43	81
18	54	34	75	40	27	51	45	72
19	51	48	67	28	24	40	29	74
20	52	49	80	50	27	49	36	67
21	54	29	74	51	25	48	42	62
22	53	16	72	51	24	32	39	61
23	58	19	70	52	55	32	45	60
24	55	25	61	65	79	33	53	57
25	52	23	55	85	86	32	67	63
26	53	24	47	62	65	26	73	55
27	50	29	54	53	58	22	58	60
28	39	34	52	51	67	27	45	61
29	47	21	38	52	57	25	60	67
30	42	18	38	50	43	26	59	62
may								
1	53	30	30	49	42	28	41	53
2	53	27	27	44	42	36	41	49
3	51	41	28	43	48	36	41	62
4	49	37	31	41	47	36	41	59
5	51	17	38	27	50	38	41	55
6	56	18	36	32	45	50	41	58
7	55	40	24	35	43	67	41	61
8	52	50	29	35	46	68	41	42
9	44	54	25	29	35	57	41	44
10	51	51	30	24	37	41	41	43
11	49	52	37	39	50	27	41	41
12	50	39	37	48	55	28	41	64
13	50	32	32	44	55	41	41	80
14	51	25	28	45	46	41	41	75
15	50	27	37	50	42	38	41	64
16	50	29	25	23	48	32	41	76
17	30	22	25	25	39	39	41	67
18	32	22	24	45	38	40	41	56
19	32	16	22	51	38	35	41	49
20	34	18	22	50	21	37	41	43
21	35	22	24	28	22	36	41	38
22	42	49	23	20	22	37	41	35
23	22	54	21	22	21	37	41	36
24	24	52	19	24	28	40	41	35
25	42	43	20	29	29	42	41	38
26	27	28	20	22	24	34	41	38
27	22	25	19	18	27	24	41	32
28	19	30	17	32	31	26	41	29
29	36	26	17	20	35	29	41	34
30	16	20	25	15	49	36	41	35
31	16	28	24	18	55	30	41	47
jun								
1	25	28	30	34	36	25	36	48
2	34	25	29	35	36	24	36	39
3	43	20	22	39	36	25	36	32
4	22	22	20	34	36	25	36	36
5	20	39	24	41	36	24	36	53
6	15	40	23	61	36	28	36	47
7	14	22	19	68	36	23	36	37
8	20	25	21	54	36	29	36	38
9	27	19	20	52	36	28	36	29
10	27	13	32	50	36	29	36	42
11	26	17	32	50	36	30	36	36
12	23	27	25	48	36	48	36	28
13	22	43	21	41	36	41	36	26
14	17	51	35	37	36	35	36	33
15	15	36	40	42	36	28	36	41
16	19	34	38	42	36	34	36	37
17	29	34	32	45	36	29	36	39
18	33	31	30	25	36	25	36	29
19	27	25	30	37	36	48	36	36
20	28	35	20	48	36	40	36	31
21	32	29	16	30	36	36	36	32
22	34	28	16	30	36	31	36	34
23	30	30	35	48	36	38	36	31
24	33	32	35	40	36	38	36	40
25	28	36	29	45	36	33	36	51
26	32	36	26	38	36	33	36	48
27	32	39	19	28	36	44	36	34
28	26	48	28	27	36	53	36	41
29	28	29	31	29	36	40	36	39
30	31	22	32	31	36	36	36	30

		1986	1987	1988	1989	1990	1991	1992	1993
jul									
	1	24	26	34	25	29	30	44	25
	2	20	20	40	24	31	30	44	29
	3	17	28	31	24	33	48	44	23
	4	25	27	20	24	34	47	44	30
	5	30	30	29	23	33	38	44	36
	6	27	30	33	31	37	40	44	42
	7	29	38	28	35	37	47	44	40
	8	34	29	36	28	32	49	44	42
	9	40	36	39	26	31	52	44	36
	10	51	31	37	35	39	37	44	34
	11	39	28	32	40	35	33	44	40
	12	37	23	36	37	25	41	44	43
	13	29	26	30	35	25	45	44	50
	14	28	30	66	37	44	40	44	47
	15	30	28	59	51	50	35	44	46
	16	24	27	50	54	42	36	44	45
	17	19	29	56	48	36	31	44	38
	18	21	29	57	49	34	37	44	40
	19	23	31	64	36	44	36	44	39
	20	27	41	63	37	40	34	44	38
	21	22	32	50	42	40	34	44	47
	22	45	33	48	52	50	33	44	44
	23	50	31	48	53	58	38	44	35
	24	51	26	77	46	63	42	44	43
	25	52	32	65	48	65	39	44	50
	26	54	34	58	49	63	34	44	41
	27	55	25	63	41	58	37	44	39
	28	50	45	77	35	49	44	44	41
	29	25	48	71	31	35	56	44	50
	30	39	39	60	32	50	49	44	51
	31	56	43	59	51	65	43	44	43
aug									
	1	51	40	59	48	50	45	50	36
	2	50	38	68	64	41	36	50	27
	3	54	43	58	60	33	28	50	23
	4	61	52	55	62	36	26	50	45
	5	62	54	48	50	49	32	50	45
	6	52	59	43	46	51	38	50	32
	7	53	58	42	58	47	38	50	25
	8	52	55	34	50	45	32	50	57
	9	51	48	43	48	32	40	50	69
	10	49	52	51	43	26	66	50	64
	11	50	56	49	45	29	53	50	55
	12	49	61	53	55	35	50	50	50
	13	47	62	39	57	39	58	50	53
	14	44	57	34	48	32	67	50	54
	15	41	53	49	43	33	56	50	48
	16	38	47	60	36	36	57	50	43
	17	50	39	54	40	38	56	50	37
	18	52	32	48	47	36	41	50	35
	19	39	29	43	50	35	32	50	28
	20	50	36	30	45	39	44	50	24
	21	40	42	38	41	32	45	50	24
	22	49	51	33	55	35	37	50	35
	23	49	49	42	49	32	36	50	31
	24	62	18	59	40	28	47	50	40
	25	54	33	47	36	20	47	50	49
	26	52	33	46	38	19	32	50	51
	27	50	29	51	24	29	26	50	54
	28	50	29	52	63	40	29	50	49
	29	49	29	62	49	47	42	50	44
	30	28	38	58	40	45	49	50	34
	31	45	38	58	25	43	45	50	28
sep									
	1	38	37	56	52	40	37	52	24
	2	28	43	56	46	40	46	39	26
	3	17	28	47	32	37	48	45	25
	4	31	30	38	38	44	42	53	38
	5	33	26	30	47	54	38	73	39
	6	48	49	23	42	45	37	65	22
	7	48	61	25	42	36	43	44	26
	8	28	59	28	35	22	44	41	26
	9	28	49	63	32	27	43	51	27
	10	32	52	51	33	36	40	51	30
	11	47	39	45	38	35	34	49	25
	12	33	30	46	35	35	32	43	29
	13	30	29	31	37	21	31	37	25
	14	51	26	46	31	19	33	37	23
	15	51	30	44	31	22	41	40	23
	16	50	25	49	35	23	40	42	23
	17	50	32	45	34	29	42	38	24
	18	27	27	37	30	32	40	40	30
	19	26	25	29	31	27	42	41	43
	20	31	28	30	26	36	46	40	36
	21	30	30	30	29	37	40	37	34
	22	30	36	30	27	37	59	41	31
	23	29	34	26	26	34	39	43	29
	24	30	31	27	35	27	24	42	33
	25	35	27	31	49	33	22	40	33
	26	28	25	24	44	29	25	37	31
	27	25	25	29	37	28	23	36	26
	28	25	25	25	33	31	25	36	27
	29	23	23	26	31	34	23	34	27
	30	23	34	27	35	40	23	56	34

oct								
1	22	43	31	40	31	26	44	31
2	26	35	29	40	27	29	44	28
3	25	30	26	40	30	35	41	27
4	26	26	27	40	28	34	32	31
5	27	24	34	40	26	35	53	32
6	26	24	43	40	29	30	60	34
7	20	27	38	40	30	36	55	31
8	35	30	36	40	30	35	77	32
9	27	39	31	40	26	29	81	34
10	24	32	28	40	22	30	64	33
11	23	31	30	40	26	31	56	41
12	23	28	29	40	23	33	54	37
13	25	23	30	40	28	31	53	34
14	20	28	32	40	27	30	55	32
15	23	28	30	40	37	31	47	37
16	25	31	32	40	42	34	44	37
17	25	31	33	40	35	35	36	50
18	27	33	35	40	38	30	38	68
19	27	29	39	40	36	35	39	42
20	23	29	37	40	35	48	34	42
21	19	27	34	40	36	55	25	35
22	20	28	36	40	35	38	27	38
23	24	45	41	40	34	34	29	51
24	25	30	44	40	35	30	29	57
25	29	30	46	40	33	31	35	35
26	19	29	40	40	31	42	39	34
27	31	32	38	40	32	35	38	33
28	33	32	35	40	33	28	37	37
29	25	29	32	40	33	32	34	44
30	25	30	27	40	29	30	37	46
31	24	30	30	40	38	40	40	51
nov								
1	21	48	31	28	35	43	42	40
2	21	37	43	20	33	37	37	37
3	41	32	49	20	34	31	38	35
4	50	32	42	22	34	28	50	36
5	37	35	39	22	38	31	51	32
6	29	35	38	26	36	29	50	39
7	30	40	38	24	35	29	46	50
8	49	28	36	21	35	28	47	49
9	51	31	32	23	35	31	47	38
10	34	38	31	34	34	40	51	40
11	26	34	33	34	38	42	59	36
12	26	29	34	31	36	41	47	30
13	40	22	39	26	34	41	47	31
14	52	20	46	22	44	37	58	36
15	39	18	51	23	47	36	53	42
16	45	22	56	24	50	41	41	43
17	35	24	55	19	52	40	40	42
18	24	28	43	18	42	39	49	40
19	22	24	38	17	40	41	54	40
20	24	30	37	18	33	42	47	42
21	28	25	38	17	35	40	34	42
22	46	28	38	17	32	43	36	34
23	28	28	38	17	40	45	36	33
24	32	37	36	17	52	57	37	34
25	29	41	35	17	52	65	45	37
26	32	38	34	17	41	58	49	39
27	37	34	34	21	41	46	52	36
28	45	39	35	18	42	37	61	33
29	28	32	34	18	51	25	65	32
30	29	27	33	26	53	29	54	37
dec								
1	41	22	37	24	51	40	53	49
2	44	28	36	23	51	42	54	38
3	51	30	47	23	49	57	57	34
4	49	33	44	29	45	69	56	31
5	58	27	43	31	70	71	49	28
6	85	38	37	42	45	62	50	33
7	58	48	40	43	50	49	51	29
8	56	49	42	48	56	52	51	30
9	53	60	41	55	53	53	52	34
10	52	53	40	66	41	41	59	34
11	47	44	49	64	35	27	57	40
12	52	29	51	50	38	25	51	44
13	52	20	51	49	40	31	45	37
14	51	18	43	52	47	46	40	34
15	48	18	39	52	47	53	42	34
16	50	30	33	59	45	50	41	39
17	47	40	33	64	42	50	44	43
18	45	40	32	65	45	60	42	49
19	40	29	38	70	41	57	51	43
20	30	27	36	59	36	55	53	37
21	40	33	30	52	37	56	49	40
22	40	26	38	54	42	55	57	38
23	40	27	40	55	46	56	66	40
24	50	34	44	50	44	51	73	45
25	29	33	36	39	42	44	66	47
26	30	31	36	43	38	40	68	55
27	22	43	39	43	43	34	65	58
28	17	37	57	53	45	38	59	46
29	18	15	63	45	49	41	51	38
30	17	66	46	42	42	41	57	27
31	41	72	36	48	42	36	55	32

SUNSHINE FRACTION

jan	1986	1987	1988	1989	1990	1991	1992	1993
1	0.86	0.95	0.53	0.93	0.86	0.86	0.86	0.86
2	0.86	0.94	0.66	0.95	0.86	0.86	0.86	0.86
3	0.86	0.96	0.77	0.94	0.86	0.86	0.86	0.86
4	0.86	0.95	0.85	0.93	0.86	0.86	0.86	0.86
5	0.86	0.91	0.90	0.94	0.86	0.86	0.86	0.86
6	0.86	0.95	0.96	0.94	0.86	0.86	0.86	0.86
7	0.86	0.95	0.95	0.94	0.86	0.86	0.86	0.86
8	0.86	0.94	0.89	0.95	0.86	0.86	0.86	0.86
9	0.86	0.94	0.92	0.96	0.86	0.86	0.86	0.86
10	0.86	0.86	0.83	0.95	0.86	0.86	0.86	0.86
11	0.86	0.95	0.96	0.92	0.86	0.86	0.86	0.86
12	0.86	0.94	0.95	0.95	0.86	0.86	0.86	0.86
13	0.86	0.92	0.92	0.88	0.86	0.86	0.86	0.86
14	0.86	0.83	0.96	0.89	0.86	0.86	0.86	0.86
15	0.86	0.94	0.96	0.80	0.86	0.86	0.86	0.86
16	0.86	0.95	0.94	0.90	0.86	0.86	0.86	0.86
17	0.86	0.95	0.92	0.77	0.86	0.86	0.86	0.86
18	0.86	0.95	0.95	0.74	0.86	0.86	0.86	0.86
19	0.86	0.95	0.90	0.83	0.86	0.86	0.86	0.86
20	0.86	0.87	0.87	0.94	0.86	0.86	0.86	0.86
21	0.86	0.95	0.93	0.95	0.86	0.86	0.86	0.86
22	0.86	0.95	0.93	0.96	0.86	0.86	0.86	0.86
23	0.86	0.91	0.96	0.95	0.86	0.86	0.86	0.86
24	0.86	0.87	0.95	0.96	0.86	0.86	0.86	0.86
25	0.86	0.86	0.95	0.96	0.86	0.86	0.86	0.86
26	0.86	0.94	0.96	0.94	0.86	0.86	0.86	0.86
27	0.86	0.89	0.92	0.96	0.86	0.86	0.86	0.86
28	0.86	0.87	0.96	0.96	0.86	0.86	0.86	0.86
29	0.86	0.95	0.93	0.96	0.86	0.86	0.86	0.86
30	0.86	0.95	0.90	0.96	0.86	0.86	0.86	0.86
31	0.86	0.93	0.96	0.96	0.86	0.86	0.86	0.86
feb								
1	0.75	0.94	0.93	0.93	0.75	0.75	0.75	0.75
2	0.75	0.95	0.93	0.91	0.75	0.75	0.75	0.75
3	0.75	0.95	0.62	0.82	0.75	0.75	0.75	0.75
4	0.75	0.95	0.78	0.24	0.75	0.75	0.75	0.75
5	0.75	0.94	0.39	0.80	0.75	0.75	0.75	0.75
6	0.75	0.94	0.54	0.97	0.75	0.75	0.75	0.75
7	0.75	0.94	0.68	0.91	0.75	0.75	0.75	0.75
8	0.75	0.94	0.91	0.94	0.75	0.75	0.75	0.75
9	0.75	0.89	0.93	1.03	0.75	0.75	0.75	0.75
10	0.75	0.89	0.95	0.94	0.75	0.75	0.75	0.75
11	0.75	0.90	0.91	0.91	0.75	0.75	0.75	0.75
12	0.75	0.89	0.91	0.76	0.75	0.75	0.75	0.75
13	0.75	0.88	0.93	0.96	0.75	0.75	0.75	0.75
14	0.75	0.92	0.82	0.69	0.75	0.75	0.75	0.75
15	0.75	0.93	0.88	0.75	0.75	0.75	0.75	0.75
16	0.75	0.83	0.64	0.81	0.75	0.75	0.75	0.75
17	0.75	0.90	0.66	0.75	0.75	0.75	0.75	0.75
18	0.75	0.78	0.77	0.93	0.75	0.75	0.75	0.75
19	0.75	0.95	0.71	0.93	0.75	0.75	0.75	0.75
20	0.75	0.91	0.69	0.95	0.75	0.75	0.75	0.75
21	0.75	0.92	0.92	0.90	0.75	0.75	0.75	0.75
22	0.75	0.66	0.22	0.97	0.75	0.75	0.75	0.75
23	0.75	0.79	0.61	0.78	0.75	0.75	0.75	0.75
24	0.75	0.81	0.56	0.72	0.75	0.75	0.75	0.75
25	0.75	0.92	0.93	0.82	0.75	0.75	0.75	0.75
26	0.75	0.85	0.74	0.84	0.75	0.75	0.75	0.75
27	0.75	0.79	0.68	0.92	0.75	0.75	0.75	0.75
28	0.75	0.81	0.78	0.89	0.75	0.75	0.75	0.75
29			0.85				0.75	
mar								
1	0.72	0.81	0.73	0.72	0.72	0.72	0.72	0.72
2	0.72	0.81	0.88	0.72	0.72	0.72	0.72	0.72
3	0.72	0.81	0.91	0.72	0.72	0.72	0.72	0.72
4	0.72	0.81	0.83	0.72	0.72	0.72	0.72	0.72
5	0.72	0.33	0.91	0.72	0.72	0.72	0.72	0.72
6	0.72	0.44	0.91	0.72	0.72	0.72	0.72	0.72
7	0.72	0.65	0.83	0.72	0.72	0.72	0.72	0.72
8	0.72	0.36	0.92	0.72	0.72	0.72	0.72	0.72
9	0.72	0.32	0.88	0.72	0.72	0.72	0.72	0.72
10	0.72	0.64	0.86	0.72	0.72	0.72	0.72	0.72
11	0.72	0.67	0.88	0.72	0.72	0.72	0.72	0.72
12	0.72	0.77	0.89	0.72	0.72	0.72	0.72	0.72
13	0.72	0.92	0.90	0.72	0.72	0.72	0.72	0.72
14	0.72	0.83	0.90	0.72	0.72	0.72	0.72	0.72
15	0.72	0.87	0.80	0.72	0.72	0.72	0.72	0.72
16	0.72	0.89	0.50	0.72	0.72	0.72	0.72	0.72
17	0.72	0.63	0.80	0.72	0.72	0.72	0.72	0.72
18	0.72	0.63	0.86	0.72	0.72	0.72	0.72	0.72
19	0.72	0.60	0.63	0.72	0.72	0.72	0.72	0.72
20	0.72	0.76	0.53	0.72	0.72	0.72	0.72	0.72
21	0.72	0.85	0.67	0.72	0.72	0.72	0.72	0.72
22	0.72	0.78	0.86	0.72	0.72	0.72	0.72	0.72
23	0.72	0.82	0.72	0.72	0.72	0.72	0.72	0.72
24	0.72	0.54	0.70	0.72	0.72	0.72	0.72	0.72
25	0.72	0.70	0.73	0.72	0.72	0.72	0.72	0.72
26	0.72	0.68	0.74	0.72	0.72	0.72	0.72	0.72
27	0.72	0.80	0.83	0.72	0.72	0.72	0.72	0.72
28	0.72	0.28	0.84	0.72	0.72	0.72	0.72	0.72
29	0.72	0.49	0.89	0.72	0.72	0.72	0.72	0.72
30	0.72	0.83	0.92	0.72	0.72	0.72	0.72	0.72
31	0.72	0.92	0.92	0.72	0.72	0.72	0.72	0.72

		1986	1987	1988	1989	1990	1991	1992	1993
apr									
	1	0.67	0.66	0.89	0.67	0.67	0.67	0.67	0.67
	2	0.67	0.73	0.84	0.67	0.67	0.67	0.67	0.67
	3	0.67	0.59	0.83	0.67	0.67	0.67	0.67	0.67
	4	0.67	0.82	0.83	0.67	0.67	0.67	0.67	0.67
	5	0.67	0.56	0.62	0.67	0.67	0.67	0.67	0.67
	6	0.67	0.14	0.52	0.67	0.67	0.67	0.67	0.67
	7	0.67	0.14	0.52	0.67	0.67	0.67	0.67	0.67
	8	0.67	0.01	0.57	0.67	0.67	0.67	0.67	0.67
	9	0.67	0.50	0.64	0.67	0.67	0.67	0.67	0.67
	10	0.67	0.29	0.52	0.67	0.67	0.67	0.67	0.67
	11	0.67	0.22	0.50	0.67	0.67	0.67	0.67	0.67
	12	0.67	0.67	0.57	0.67	0.67	0.67	0.67	0.67
	13	0.67	0.41	0.56	0.67	0.67	0.67	0.67	0.67
	14	0.67	0.57	0.57	0.67	0.67	0.67	0.67	0.67
	15	0.67	0.94	0.61	0.67	0.67	0.67	0.67	0.67
	16	0.67	0.94	0.60	0.67	0.67	0.67	0.67	0.67
	17	0.67	0.89	0.60	0.67	0.67	0.67	0.67	0.67
	18	0.67	0.91	0.67	0.67	0.67	0.67	0.67	0.67
	19	0.67	0.90	0.52	0.67	0.67	0.67	0.67	0.67
	20	0.67	0.92	0.67	0.67	0.67	0.67	0.67	0.67
	21	0.67	0.92	0.61	0.67	0.67	0.67	0.67	0.67
	22	0.67	0.94	0.67	0.67	0.67	0.67	0.67	0.67
	23	0.67	0.94	0.63	0.67	0.67	0.67	0.67	0.67
	24	0.67	0.92	0.79	0.67	0.67	0.67	0.67	0.67
	25	0.67	0.94	0.94	0.67	0.67	0.67	0.67	0.67
	26	0.67	0.90	0.85	0.67	0.67	0.67	0.67	0.67
	27	0.67	0.92	0.84	0.67	0.67	0.67	0.67	0.67
	28	0.67	0.94	0.68	0.67	0.67	0.67	0.67	0.67
	29	0.67	0.94	0.83	0.67	0.67	0.67	0.67	0.67
	30	0.67	0.94	0.83	0.67	0.67	0.67	0.67	0.67
may									
	1	0.72	0.91	0.91	0.90	0.72	0.72	0.72	0.72
	2	0.72	0.88	0.91	0.93	0.72	0.72	0.72	0.72
	3	0.72	0.83	0.91	0.90	0.72	0.72	0.72	0.72
	4	0.72	0.44	0.91	0.93	0.72	0.72	0.72	0.72
	5	0.72	0.85	0.88	0.94	0.72	0.72	0.72	0.72
	6	0.72	0.91	0.91	0.95	0.72	0.72	0.72	0.72
	7	0.72	0.69	0.91	0.94	0.72	0.72	0.72	0.72
	8	0.72	0.41	0.86	0.95	0.72	0.72	0.72	0.72
	9	0.72	0.42	0.90	0.94	0.72	0.72	0.72	0.72
	10	0.72	0.55	0.91	0.92	0.72	0.72	0.72	0.72
	11	0.72	0.47	0.81	0.95	0.72	0.72	0.72	0.72
	12	0.72	0.78	0.69	0.75	0.72	0.72	0.72	0.72
	13	0.72	0.90	0.77	0.67	0.72	0.72	0.72	0.72
	14	0.72	0.64	0.89	0.86	0.72	0.72	0.72	0.72
	15	0.72	0.79	0.88	0.90	0.72	0.72	0.72	0.72
	16	0.72	0.71	0.67	0.69	0.72	0.72	0.72	0.72
	17	0.72	0.90	0.83	0.59	0.72	0.72	0.72	0.72
	18	0.72	0.88	0.87	0.66	0.72	0.72	0.72	0.72
	19	0.72	0.84	0.72	0.91	0.72	0.72	0.72	0.72
	20	0.72	0.47	0.88	0.93	0.72	0.72	0.72	0.72
	21	0.72	0.09	0.84	0.94	0.72	0.72	0.72	0.72
	22	0.72	0.21	0.83	0.91	0.72	0.72	0.72	0.72
	23	0.72	0.32	0.85	0.87	0.72	0.72	0.72	0.72
	24	0.72	0.51	0.88	0.90	0.72	0.72	0.72	0.72
	25	0.72	0.63	0.85	0.94	0.72	0.72	0.72	0.72
	26	0.72	0.82	0.88	0.90	0.72	0.72	0.72	0.72
	27	0.72	0.95	0.91	0.88	0.72	0.72	0.72	0.72
	28	0.72	0.80	0.92	0.88	0.72	0.72	0.72	0.72
	29	0.72	0.87	0.93	0.85	0.72	0.72	0.72	0.72
	30	0.72	0.64	0.73	0.87	0.72	0.72	0.72	0.72
	31	0.72	0.62	0.74	0.89	0.72	0.72	0.72	0.72
jun									
	1	0.64	0.86	0.88	0.86	0.64	0.64	0.64	0.64
	2	0.64	0.85	0.85	0.83	0.64	0.64	0.64	0.64
	3	0.64	0.88	0.82	0.67	0.64	0.64	0.64	0.64
	4	0.64	0.66	0.89	0.77	0.64	0.64	0.64	0.64
	5	0.64	0.16	0.80	0.74	0.64	0.64	0.64	0.64
	6	0.64	0.44	0.90	0.33	0.64	0.64	0.64	0.64
	7	0.64	0.70	0.89	0.77	0.64	0.64	0.64	0.64
	8	0.64	0.65	0.83	0.82	0.64	0.64	0.64	0.64
	9	0.64	0.72	0.85	0.87	0.64	0.64	0.64	0.64
	10	0.64	0.60	0.90	0.81	0.64	0.64	0.64	0.64
	11	0.64	0.72	0.71	0.83	0.64	0.64	0.64	0.64
	12	0.64	0.73	0.87	0.81	0.64	0.64	0.64	0.64
	13	0.64	0.63	0.83	0.90	0.64	0.64	0.64	0.64
	14	0.64	0.38	0.63	0.79	0.64	0.64	0.64	0.64
	15	0.64	0.63	0.81	0.62	0.64	0.64	0.64	0.64
	16	0.64	0.67	0.71	0.71	0.64	0.64	0.64	0.64
	17	0.64	0.85	0.74	0.70	0.64	0.64	0.64	0.64
	18	0.64	0.85	0.64	0.82	0.64	0.64	0.64	0.64
	19	0.64	0.87	0.66	0.80	0.64	0.64	0.64	0.64
	20	0.64	0.88	0.84	0.85	0.64	0.64	0.64	0.64
	21	0.64	0.86	0.87	0.77	0.64	0.64	0.64	0.64
	22	0.64	0.73	0.90	0.88	0.64	0.64	0.64	0.64
	23	0.64	0.83	0.86	0.76	0.64	0.64	0.64	0.64
	24	0.64	0.85	0.74	0.53	0.64	0.64	0.64	0.64
	25	0.64	0.89	0.87	0.78	0.64	0.64	0.64	0.64
	26	0.64	0.85	0.85	0.84	0.64	0.64	0.64	0.64
	27	0.64	0.85	0.84	0.88	0.64	0.64	0.64	0.64
	28	0.64	0.79	0.82	0.69	0.64	0.64	0.64	0.64
	29	0.64	0.62	0.81	0.67	0.64	0.64	0.64	0.64
	30	0.64	0.83	0.73	0.71	0.64	0.64	0.64	0.64

jul									
	1	0.57	0.82	0.43	0.80	0.57	0.57	0.57	0.57
	2	0.57	0.85	0.32	0.65	0.57	0.57	0.57	0.57
	3	0.57	0.75	0.85	0.55	0.57	0.57	0.57	0.57
	4	0.57	0.79	0.75	0.62	0.57	0.57	0.57	0.57
	5	0.57	0.73	0.46	0.74	0.57	0.57	0.57	0.57
	6	0.57	0.83	0.75	0.68	0.57	0.57	0.57	0.57
	7	0.57	0.82	0.55	0.50	0.57	0.57	0.57	0.57
	8	0.57	0.78	0.49	0.77	0.57	0.57	0.57	0.57
	9	0.57	0.77	0.38	0.72	0.57	0.57	0.57	0.57
	10	0.57	0.65	0.63	0.59	0.57	0.57	0.57	0.57
	11	0.57	0.55	0.72	0.63	0.57	0.57	0.57	0.57
	12	0.57	0.69	0.65	0.68	0.57	0.57	0.57	0.57
	13	0.57	0.63	0.70	0.56	0.57	0.57	0.57	0.57
	14	0.57	0.59	0.13	0.47	0.57	0.57	0.57	0.57
	15	0.57	0.60	0.04	0.69	0.57	0.57	0.57	0.57
	16	0.57	0.72	0.32	0.57	0.57	0.57	0.57	0.57
	17	0.57	0.61	0.38	0.66	0.57	0.57	0.57	0.57
	18	0.57	0.85	0.54	0.51	0.57	0.57	0.57	0.57
	19	0.57	0.87	0.55	0.65	0.57	0.57	0.57	0.57
	20	0.57	0.78	0.50	0.78	0.57	0.57	0.57	0.57
	21	0.57	0.82	0.23	0.38	0.57	0.57	0.57	0.57
	22	0.57	0.51	0.42	0.68	0.57	0.57	0.57	0.57
	23	0.57	0.88	0.45	0.47	0.57	0.57	0.57	0.57
	24	0.57	0.78	0.02	0.37	0.57	0.57	0.57	0.57
	25	0.57	0.68	0.19	0.43	0.57	0.57	0.57	0.57
	26	0.57	0.83	0.66	0.64	0.57	0.57	0.57	0.57
	27	0.57	0.81	0.63	0.79	0.57	0.57	0.57	0.57
	28	0.57	0.61	0.44	0.82	0.57	0.57	0.57	0.57
	29	0.57	0.76	0.42	0.84	0.57	0.57	0.57	0.57
	30	0.57	0.77	0.52	0.67	0.57	0.57	0.57	0.57
	31	0.57	0.52	0.73	0.57	0.57	0.57	0.57	0.57
aug									
	1	0.58	0.58	0.37	0.58	0.58	0.58	0.58	0.58
	2	0.58	0.71	0.41	0.58	0.58	0.58	0.58	0.58
	3	0.58	0.53	0.60	0.58	0.58	0.58	0.58	0.58
	4	0.58	0.40	0.61	0.58	0.58	0.58	0.58	0.58
	5	0.58	0.58	0.55	0.58	0.58	0.58	0.58	0.58
	6	0.58	0.17	0.82	0.58	0.58	0.58	0.58	0.58
	7	0.58	0.68	0.65	0.58	0.58	0.58	0.58	0.58
	8	0.58	0.91	0.79	0.58	0.58	0.58	0.58	0.58
	9	0.58	0.73	0.65	0.58	0.58	0.58	0.58	0.58
	10	0.58	0.62	0.52	0.58	0.58	0.58	0.58	0.58
	11	0.58	0.46	0.54	0.58	0.58	0.58	0.58	0.58
	12	0.58	0.67	0.50	0.58	0.58	0.58	0.58	0.58
	13	0.58	0.52	0.77	0.58	0.58	0.58	0.58	0.58
	14	0.58	0.60	0.78	0.58	0.58	0.58	0.58	0.58
	15	0.58	0.77	0.62	0.58	0.58	0.58	0.58	0.58
	16	0.58	0.70	0.50	0.58	0.58	0.58	0.58	0.58
	17	0.58	0.65	0.72	0.58	0.58	0.58	0.58	0.58
	18	0.58	0.62	0.68	0.58	0.58	0.58	0.58	0.58
	19	0.58	0.79	0.68	0.58	0.58	0.58	0.58	0.58
	20	0.58	0.73	0.60	0.58	0.58	0.58	0.58	0.58
	21	0.58	0.38	0.53	0.58	0.58	0.58	0.58	0.58
	22	0.58	0.46	0.84	0.58	0.58	0.58	0.58	0.58
	23	0.58	0.61	0.84	0.58	0.58	0.58	0.58	0.58
	24	0.58	0.84	0.56	0.58	0.58	0.58	0.58	0.58
	25	0.58	0.61	0.67	0.58	0.58	0.58	0.58	0.58
	26	0.58	0.31	0.57	0.58	0.58	0.58	0.58	0.58
	27	0.58	0.40	0.56	0.58	0.58	0.58	0.58	0.58
	28	0.58	0.65	0.48	0.58	0.58	0.58	0.58	0.58
	29	0.58	0.72	0.50	0.58	0.58	0.58	0.58	0.58
	30	0.58	0.25	0.45	0.58	0.58	0.58	0.58	0.58
	31	0.58	0.51	0.82	0.58	0.58	0.58	0.58	0.58
sep									
	1	0.67	0.57	0.60	0.67	0.67	0.67	0.67	0.67
	2	0.67	0.83	0.45	0.67	0.67	0.67	0.67	0.67
	3	0.67	0.89	0.81	0.67	0.67	0.67	0.67	0.67
	4	0.67	0.82	0.65	0.67	0.67	0.67	0.67	0.67
	5	0.67	0.87	0.68	0.67	0.67	0.67	0.67	0.67
	6	0.67	0.52	0.75	0.67	0.67	0.67	0.67	0.67
	7	0.67	0.75	0.88	0.67	0.67	0.67	0.67	0.67
	8	0.67	0.64	0.82	0.67	0.67	0.67	0.67	0.67
	9	0.67	0.74	0.57	0.67	0.67	0.67	0.67	0.67
	10	0.67	0.80	0.42	0.67	0.67	0.67	0.67	0.67
	11	0.67	0.81	0.13	0.67	0.67	0.67	0.67	0.67
	12	0.67	0.84	0.69	0.67	0.67	0.67	0.67	0.67
	13	0.67	0.84	0.82	0.67	0.67	0.67	0.67	0.67
	14	0.67	0.57	0.61	0.67	0.67	0.67	0.67	0.67
	15	0.67	0.80	0.75	0.67	0.67	0.67	0.67	0.67
	16	0.67	0.90	0.74	0.67	0.67	0.67	0.67	0.67
	17	0.67	0.90	0.87	0.67	0.67	0.67	0.67	0.67
	18	0.67	0.85	0.75	0.67	0.67	0.67	0.67	0.67
	19	0.67	0.90	0.86	0.67	0.67	0.67	0.67	0.67
	20	0.67	0.86	0.36	0.67	0.67	0.67	0.67	0.67
	21	0.67	0.91	0.48	0.67	0.67	0.67	0.67	0.67
	22	0.67	0.89	0.50	0.67	0.67	0.67	0.67	0.67
	23	0.67	0.89	0.89	0.67	0.67	0.67	0.67	0.67
	24	0.67	0.91	0.89	0.67	0.67	0.67	0.67	0.67
	25	0.67	0.90	0.67	0.67	0.67	0.67	0.67	0.67
	26	0.67	0.89	0.68	0.67	0.67	0.67	0.67	0.67
	27	0.67	0.89	0.53	0.67	0.67	0.67	0.67	0.67
	28	0.67	0.85	0.90	0.67	0.67	0.67	0.67	0.67
	29	0.67	0.57	0.89	0.67	0.67	0.67	0.67	0.67
	30	0.67	0.89	0.89	0.67	0.67	0.67	0.67	0.67

oct									
	1	0.76	0.80	0.91	0.76	0.76	0.76	0.76	0.76
	2	0.76	0.94	0.83	0.76	0.76	0.76	0.76	0.76
	3	0.76	0.94	0.92	0.76	0.76	0.76	0.76	0.76
	4	0.76	0.74	0.92	0.76	0.76	0.76	0.76	0.76
	5	0.76	0.92	0.92	0.76	0.76	0.76	0.76	0.76
	6	0.76	0.93	0.94	0.76	0.76	0.76	0.76	0.76
	7	0.76	0.92	0.92	0.76	0.76	0.76	0.76	0.76
	8	0.76	0.93	0.89	0.76	0.76	0.76	0.76	0.76
	9	0.76	0.93	0.92	0.76	0.76	0.76	0.76	0.76
	10	0.76	0.92	0.92	0.76	0.76	0.76	0.76	0.76
	11	0.76	0.92	0.87	0.76	0.76	0.76	0.76	0.76
	12	0.76	0.85	0.93	0.76	0.76	0.76	0.76	0.76
	13	0.76	0.92	0.87	0.76	0.76	0.76	0.76	0.76
	14	0.76	0.93	0.91	0.76	0.76	0.76	0.76	0.76
	15	0.76	0.90	0.95	0.76	0.76	0.76	0.76	0.76
	16	0.76	0.93	0.95	0.76	0.76	0.76	0.76	0.76
	17	0.76	0.92	0.96	0.76	0.76	0.76	0.76	0.76
	18	0.76	0.93	0.96	0.76	0.76	0.76	0.76	0.76
	19	0.76	0.92	0.95	0.76	0.76	0.76	0.76	0.76
	20	0.76	0.92	0.94	0.76	0.76	0.76	0.76	0.76
	21	0.76	0.92	0.93	0.76	0.76	0.76	0.76	0.76
	22	0.76	0.91	0.92	0.76	0.76	0.76	0.76	0.76
	23	0.76	0.92	0.92	0.76	0.76	0.76	0.76	0.76
	24	0.76	0.91	0.92	0.76	0.76	0.76	0.76	0.76
	25	0.76	0.75	0.92	0.76	0.76	0.76	0.76	0.76
	26	0.76	0.90	0.92	0.76	0.76	0.76	0.76	0.76
	27	0.76	0.86	0.93	0.76	0.76	0.76	0.76	0.76
	28	0.76	0.86	0.92	0.76	0.76	0.76	0.76	0.76
	29	0.76	0.85	0.93	0.76	0.76	0.76	0.76	0.76
	30	0.76	0.90	0.93	0.76	0.76	0.76	0.76	0.76
	31	0.76	0.76	0.92	0.76	0.76	0.76	0.76	0.76
nov									
	1	0.88	0.93	0.96	0.88	0.88	0.88	0.88	0.88
	2	0.88	0.90	0.96	0.88	0.88	0.88	0.88	0.88
	3	0.88	0.90	0.96	0.88	0.88	0.88	0.88	0.88
	4	0.88	0.96	0.95	0.88	0.88	0.88	0.88	0.88
	5	0.88	0.95	0.96	0.88	0.88	0.88	0.88	0.88
	6	0.88	0.94	0.96	0.88	0.88	0.88	0.88	0.88
	7	0.88	0.95	0.96	0.88	0.88	0.88	0.88	0.88
	8	0.88	0.94	0.96	0.88	0.88	0.88	0.88	0.88
	9	0.88	0.84	0.96	0.88	0.88	0.88	0.88	0.88
	10	0.88	0.89	0.96	0.88	0.88	0.88	0.88	0.88
	11	0.88	0.94	0.96	0.88	0.88	0.88	0.88	0.88
	12	0.88	0.78	0.96	0.88	0.88	0.88	0.88	0.88
	13	0.88	0.84	0.93	0.88	0.88	0.88	0.88	0.88
	14	0.88	0.87	0.96	0.88	0.88	0.88	0.88	0.88
	15	0.88	0.84	0.93	0.88	0.88	0.88	0.88	0.88
	16	0.88	0.93	0.69	0.88	0.88	0.88	0.88	0.88
	17	0.88	0.88	0.89	0.88	0.88	0.88	0.88	0.88
	18	0.88	0.86	0.94	0.88	0.88	0.88	0.88	0.88
	19	0.88	0.91	0.94	0.88	0.88	0.88	0.88	0.88
	20	0.88	0.94	0.95	0.88	0.88	0.88	0.88	0.88
	21	0.88	0.93	0.96	0.88	0.88	0.88	0.88	0.88
	22	0.88	0.93	0.95	0.88	0.88	0.88	0.88	0.88
	23	0.88	0.94	0.93	0.88	0.88	0.88	0.88	0.88
	24	0.88	0.83	0.93	0.88	0.88	0.88	0.88	0.88
	25	0.88	0.82	0.92	0.88	0.88	0.88	0.88	0.88
	26	0.88	0.93	0.92	0.88	0.88	0.88	0.88	0.88
	27	0.88	0.92	0.93	0.88	0.88	0.88	0.88	0.88
	28	0.88	0.92	0.94	0.88	0.88	0.88	0.88	0.88
	29	0.88	0.83	0.95	0.88	0.88	0.88	0.88	0.88
	30	0.88	0.94	0.94	0.88	0.88	0.88	0.88	0.88
dec									
	1	0.85	0.94	0.96	0.85	0.85	0.85	0.85	0.85
	2	0.85	0.85	0.96	0.85	0.85	0.85	0.85	0.85
	3	0.85	0.93	0.94	0.85	0.85	0.85	0.85	0.85
	4	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	5	0.85	0.94	0.95	0.85	0.85	0.85	0.85	0.85
	6	0.85	0.86	0.92	0.85	0.85	0.85	0.85	0.85
	7	0.85	0.70	0.93	0.85	0.85	0.85	0.85	0.85
	8	0.85	0.77	0.89	0.85	0.85	0.85	0.85	0.85
	9	0.85	0.91	0.80	0.85	0.85	0.85	0.85	0.85
	10	0.85	0.92	0.95	0.85	0.85	0.85	0.85	0.85
	11	0.85	0.95	0.95	0.85	0.85	0.85	0.85	0.85
	12	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	13	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	14	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	15	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	16	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	17	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	18	0.85	0.95	0.96	0.85	0.85	0.85	0.85	0.85
	19	0.85	0.94	0.95	0.85	0.85	0.85	0.85	0.85
	20	0.85	0.92	0.93	0.85	0.85	0.85	0.85	0.85
	21	0.85	0.94	0.96	0.85	0.85	0.85	0.85	0.85
	22	0.85	0.92	0.96	0.85	0.85	0.85	0.85	0.85
	23	0.85	0.93	0.97	0.85	0.85	0.85	0.85	0.85
	24	0.85	0.79	0.95	0.85	0.85	0.85	0.85	0.85
	25	0.85	0.89	0.96	0.85	0.85	0.85	0.85	0.85
	26	0.85	0.95	0.96	0.85	0.85	0.85	0.85	0.85
	27	0.85	0.96	0.96	0.85	0.85	0.85	0.85	0.85
	28	0.85	0.88	0.90	0.85	0.85	0.85	0.85	0.85
	29	0.85	0.73	0.77	0.85	0.85	0.85	0.85	0.85
	30	0.85	0.78	0.90	0.85	0.85	0.85	0.85	0.85
	31	0.85	0.36	0.93	0.85	0.85	0.85	0.85	0.85

APPLE 1993		mean temp mean °C	rh %	radiation Langley	wind speed m/s	pressure mb	sunshine fraction	Aerodynamic Resistance (ln((z-d)/zo)) i2/f2	ra m/s	e*	ea measured	spec humid kgwater/kg	moist air j/kg/k	air density kg/m3	gradient mb/C	psychrom mb/k	Rn w/m2	Rn** W/m2	Rn-G W/m2	final P-M equ	actual evap mm
jan																					
	1	15.6	47	233.3	2.1	790	0.86	129.61	80.59	17.72	7.9	0.01	288.13	0.95	1.13	0.52	75.27	111.36	77.95	44.02	1.55
	2	15.9	42	233.3	1.7	789.3	0.86	129.61	77.53	18.07	7.1	0.01	288.02	0.95	1.15	0.52	77.83	108.80	76.16	47.42	1.67
	3	16.6	48	233.3	2.5	788.2	0.86	129.61	52.13	18.89	8.5	0.01	288.21	0.94	1.20	0.52	74.69	111.93	78.35	45.62	1.61
	4	16.4	42	233.3	1.5	787.1	0.86	129.61	83.99	18.65	7.3	0.01	288.05	0.94	1.19	0.52	77.80	108.83	76.18	48.72	1.72
	5	16	32	233.3	1.3	786.3	0.86	129.61	97.54	18.18	4.9	0.00	287.72	0.94	1.16	0.52	84.88	101.75	71.22	52.08	1.83
	6	15	27	233.3	1.7	788.7	0.86	129.61	78.53	17.05	4.2	0.00	287.62	0.95	1.10	0.52	86.21	100.42	70.29	50.83	1.79
	7	14.7	31	233.3	1.3	788.5	0.86	129.61	97.54	16.73	4.6	0.00	287.67	0.95	1.08	0.52	84.41	102.22	71.55	49.07	1.73
	8	16	33	233.3	1.5	787.1	0.86	129.61	86.39	18.18	4.9	0.00	287.72	0.95	1.16	0.52	84.88	101.75	71.22	52.21	1.84
	9	16.3	38	233.3	1.5	787.5	0.86	129.61	86.39	18.53	6	0.00	287.87	0.94	1.18	0.52	81.59	105.04	73.53	50.89	1.79
	10	15.5	39	233.3	1.7	787.3	0.86	129.61	75.59	17.61	5.7	0.00	287.83	0.95	1.13	0.52	81.64	104.99	73.49	49.17	1.73
	11	15.3	49	233.3	1.6	786.6	0.86	129.61	82.39	17.39	7.2	0.01	288.04	0.95	1.11	0.52	76.90	109.73	76.81	45.51	1.60
	12	15.8	48	233.3	1.4	785.9	0.86	129.61	89.46	17.95	8.3	0.01	288.19	0.94	1.15	0.52	74.40	112.23	78.56	45.05	1.59
	13	15.8	58	233.3	2.2	787.3	0.86	129.61	59.29	17.95	10.1	0.01	288.43	0.94	1.15	0.52	69.84	116.79	81.75	39.15	1.38
	14	12.5	68	233.3	1.6	787.3	0.86	129.61	80.63	14.49	9.7	0.01	288.38	0.96	0.95	0.52	67.64	118.99	83.29	31.21	1.10
	15	11.5	70	233.3	1.7	786.5	0.86	129.61	75.21	13.57	8	0.01	288.15	0.96	0.90	0.52	70.83	115.79	81.06	31.89	1.12
	16	12.1	60	233.3	1.6	786.9	0.86	129.61	81.94	14.12	7.9	0.01	288.13	0.96	0.93	0.52	71.69	114.94	80.46	34.38	1.21
	17	12.8	52	233.3	1.1	787.4	0.86	129.61	116.29	14.78	7.4	0.01	288.06	0.96	0.97	0.52	73.73	112.90	79.03	39.32	1.38
	18	12.4	41	233.3	1.1	787.2	0.86	129.61	120.94	14.40	5.6	0.00	287.81	0.96	0.94	0.52	78.50	108.13	75.69	41.70	1.47
	19	14	44	233.3	2.7	787.1	0.86	129.61	47.77	15.99	6.7	0.01	287.97	0.95	1.04	0.52	76.95	109.68	76.78	41.20	1.45
	20	13.9	43	233.3	1.3	787.5	0.86	129.61	97.54	15.88	6.1	0.00	287.88	0.95	1.03	0.52	78.61	108.01	75.61	44.09	1.55
	21	14.2	49	233.3	2.5	787.5	0.86	129.61	51.77	16.19	7.7	0.01	288.10	0.95	1.05	0.52	74.36	112.27	78.59	39.34	1.38
	22	14.7	60	233.3	1.7	788.4	0.86	129.61	76.55	16.73	9.7	0.01	288.38	0.95	1.08	0.52	69.75	116.88	81.82	37.78	1.33
	23	15.3	61	233.3	1.9	788.4	0.86	129.61	67.04	17.39	10.4	0.01	288.47	0.95	1.11	0.52	68.65	117.98	82.59	37.34	1.31
	24	14.7	62	233.3	1.5	787	0.86	129.61	87.14	16.73	10.3	0.01	288.46	0.95	1.08	0.52	68.31	118.32	82.82	37.30	1.31
	25	13.3	71	233.3	1.6	786.8	0.86	129.61	81.72	15.27	10.6	0.01	288.50	0.95	0.99	0.52	66.31	120.32	84.23	31.70	1.12
	26	12.1	74	233.3	1.8	788.8	0.86	129.61	73.75	14.12	10.7	0.01	288.51	0.96	0.93	0.52	64.98	121.65	85.16	26.77	0.94
	27	13.4	67	233.3	1.0	790.1	0.86	129.61	125.98	15.37	9.9	0.01	288.40	0.96	1.00	0.52	68.02	118.61	83.03	36.91	1.30
	28	13.8	60	233.3	1.2	790	0.86	129.61	109.55	15.78	8.7	0.01	288.24	0.95	1.02	0.52	71.34	115.29	80.70	39.27	1.38
	29	14.8	56	233.3	2.0	789.8	0.86	129.61	64.61	16.84	8.8	0.01	288.22	0.95	1.08	0.52	72.60	114.03	79.82	39.84	1.40
	30	16.2	52	233.3	2.2	788.4	0.86	129.61	58.71	18.42	9.2	0.01	288.31	0.94	1.17	0.52	72.47	114.16	79.91	42.77	1.51
	31	17.5	49	233.3	2.5	787.2	0.86	129.61	52.13	20.00	8.8	0.01	288.26	0.94	1.26	0.52	74.82	111.80	78.26	48.17	1.70
feb								129.61		6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	
	1	17.7	46	237.5	2.2	786.6	0.75	129.61	60.23	20.25	8.8	0.01	288.26	0.94	1.27	0.52	67.80	122.37	85.66	50.90	1.79
	2	18.1	54	237.5	1.2	786	0.75	129.61	107.99	20.77	10.4	0.01	288.48	0.94	1.30	0.52	64.28	125.68	87.98	51.48	1.81
	3	17.2	57	237.5	1.1	785.8	0.75	129.61	121.92	19.62	10.9	0.01	288.55	0.94	1.24	0.52	62.41	127.56	89.28	48.54	1.71
	4	16.5	58	237.5	1.8	785.7	0.75	129.61	71.99	18.77	10.7	0.01	288.52	0.94	1.19	0.52	62.23	127.73	89.41	42.96	1.51
	5	16.5	61	237.5	1.7	785.9	0.75	129.61	75.59	18.77	11.4	0.01	288.62	0.94	1.19	0.52	60.76	129.20	90.44	41.70	1.47
	6	12.8	70	237.5	2.0	786.5	0.75	129.61	64.06	14.78	10.4	0.01	288.48	0.95	0.97	0.52	59.73	130.24	91.16	29.97	1.06
	7	8.7	72	237.5	2.2	788.1	0.75	129.61	58.82	11.25	8.1	0.01	288.16	0.97	0.76	0.52	61.12	128.84	90.19	22.99	0.81
	8	12.8	58	237.5	1.4	787.3	0.75	129.61	89.46	14.78	8.2	0.01	288.17	0.95	0.97	0.52	64.52	125.44	87.81	37.97	1.34
	9	13.6	57	237.5	2.2	787.2	0.75	129.61	59.52	15.58	8.6	0.01	288.23	0.95	1.01	0.52	64.32	125.64	87.95	36.88	1.30
	10	14.5	62	237.5	2.1	786.5	0.75	129.61	61.71	16.51	9.7	0.01	288.38	0.95	1.07	0.52	62.66	127.30	89.11	37.30	1.31
	11	14.2	67	237.5	2.3	786.7	0.75	129.61	57.26	16.19	10.2	0.01	288.45	0.95	1.05	0.52	61.33	128.64	90.05	34.42	1.21
	12	13.4	81	237.5	2.1	788.1	0.75	129.61	61.08	15.37	12.3	0.01	288.74	0.95	1.00	0.52	56.46	133.51	93.46	26.50	0.93
	13	16.4	61	237.5	2.3	787.7	0.75	129.61	55.26	18.65	10.5	0.01	288.49	0.94	1.18	0.52	62.58	127.39	89.17	41.38	1.46
	14	16.4	49	237.5	2.0	787.3	0.75	129.61	64.33	18.65	8.7	0.01	288.24	0.94	1.19	0.52	66.63	123.33	86.33	46.67	1.64
	15	17.1	49	237.5	1.3	786.9	0.75	129.61	97.54	19.50	8.8	0.01	288.26	0.94	1.23	0.52	67.04	122.92	86.05	50.61	1.78
	16	17.2	38	237.5	1.9	786.4	0.75	129.61	68.10	19.62	7.3	0.01	288.05	0.94	1.24	0.52	70.86	119.10	83.37	52.92	1.86
	17	16.5	45	237.5	2.1	786.3	0.75	129.61	61.71	18.77	7.9	0.01	288.13	0.94	1.19	0.52	68.66	121.30	84.91	48.82	1.72
	18	17.4	42	237.5	2.2	786.8	0.75	129.61	57.92	19.87	7.7	0.01	288.10	0.94	1.25	0.52	70.03	119.94	83.96	52.35	1.84
	19	17.2	37	237.5	2.6	787.6	0.75	129.61	50.65	19.62	6.6	0.01	287.95	0.94	1.24	0.52	72.74	117.23	82.06	54.17	1.91
	20	18	24	237.5	2.7	787.2	0.75	129.61	47.77	20.64	4.4	0.00	287.65	0.94	1.30	0.52	80.26	109.70	76.79	62.75	2.21
	21	18.8	28	237.5	2.5	786.5	0.75	129.61	52.40	21.70	4.8	0.00	287.70	0.94	1.35	0.52	79.80	110.16	77.11	64.49	2.27
	22	18.2	31	237.5	2.2	787.1	0.75	129.61	59.29	20.90	6.2	0.00	287.90	0.94	1.31	0.52	74.87	115.09	80.56	58.84	2.07
	23	17.8	42	237.5	1.8	787.6	0.75	129.61	71.14	20.38	8.4	0.01	288.20	0.94	1.28	0.52	68.66	121.31	84.91	52.66	1.86
	24	16.8	55	237.5	2.7	788	0.75	129.61	47.99	19.13	9.9	0.01	288.41	0.94	1.21	0.52	64.24	125.72	88.01	43.75	1.54
	25	13.9	51	237.5	1.7	789.2	0.75	129.61	78.13	15.88	7.8	0.01	288.11	0.95	1.03	0.52	66.47	123.49	86.44	41.40	1.46
	26	14.4	34	237.5	1.8	788.6	0.75	129.61	70.64	16.41	5.3	0.00	287.77	0.95	1.06	0.52	73.58	116.37	81.46	48.43	1.70
	27	14.1	29	237.5	1.2	788	0.75	129.61	107.22	16.09	4	0.00	287.59	0.95	1.04	0.52	77.37	112.60	78.82	50.83	1.79
	28	14.4	29	237.5	2.2	787.7	0.75	129.61	60.11	16.41	4.1	0.00	287.61	0.95	1.06	0.52	77.36	112.61	78.83	51.12	1.80

mar								129.61		6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	
	1	14.6	26	256.0	1.5	788.4	0.72	129.61	87.14	16.62	3.7	0.00	287.55	0.95	1.07	0.52	76.58	128.20	89.74	55.69	1.96
	2	14.1	25	256.0	1.8	788.9	0.72	129.61	70.81	16.09	3.6	0.00	287.54	0.95	1.04	0.52	76.39	128.38	89.87	54.02	1.90
	3	14	25	256.0	1.5	789.1	0.72	129.61	86.88	15.99	3.6	0.00	287.54	0.96	1.04	0.52	76.29	128.49	89.94	54.13	1.91
	4	14.7	28	256.0	1.8	787.9	0.72	129.61	71.48	16.73	4.5	0.00	287.66	0.95	1.08	0.52	74.07	130.70	91.49	53.86	1.90
	5	17.1	33	256.0	2.3	785.5	0.72	129.61	57.05	19.50	5.7	0.00	287.83	0.94	1.23	0.52	72.94	131.84	92.29	58.66	2.06
	6	18.2	36	256.0	2.5	785	0.72	129.61	51.42	20.90	7.2	0.01	288.04	0.93	1.31	0.52	69.95	134.83	94.38	58.85	2.07
	7	19.1	43	256.0	1.7	785.8	0.72	129.61	77.53	22.11	9	0.01	288.29	0.93	1.38	0.52	66.37	138.41	96.88	59.55	2.10
	8	19.5	46	256.0	1.6	787	0.72	129.61	80.20	22.67	10.2	0.01	288.45	0.93	1.41	0.52	64.00	140.78	98.54	58.77	2.07
	9	19.9	50	256.0	2.0	787.6	0.72	129.61	63.65	23.24	10.7	0.01	288.52	0.93	1.44	0.52	63.25	141.53	99.07	58.07	2.04
	10	19.9	47	256.0	2.1	787.9	0.72	129.61	61.48	23.24	10.5	0.01	288.49	0.93	1.44	0.52	63.69	141.09	98.76	58.35	2.05
	11	20.1	43	256.0	2.3	788.1	0.72	129.61	55.48	23.53	9.8	0.01	288.39	0.93	1.45	0.52	65.42	139.35	97.55	60.36	2.12
	12	20	51	256.0	1.8	787.9	0.72	129.61	70.48	23.38	11.3	0.01	288.60	0.93	1.44	0.52	62.05	142.72	99.91	57.72	2.03
	13	18.9	49	256.0	1.5	788.2	0.72	129.61	84.22	21.84	10.3	0.01	288.46	0.94	1.36	0.52	63.26	141.52	99.06	56.61	1.99
	14	19	40	256.0	1.6	788	0.72	129.61	81.28	21.97	8.3	0.01	288.19	0.94	1.37	0.52	67.95	136.83	95.78	60.73	2.14
	15	19	47	256.0	1.4	787.5	0.72	129.61	92.18	21.97	9.7	0.01	288.38	0.93	1.37	0.52	64.67	140.10	98.07	58.64	2.06
	16	19	52	256.0	2.6	786.1	0.72	129.61	50.23	21.97	11.1	0.01	288.58	0.93	1.37	0.52	61.63	143.15	100.20	52.07	1.83
	17	18.3	52	256.0	1.6	785	0.72	129.61	79.99	21.03	10.7	0.01	288.52	0.93	1.32	0.52	61.88	142.89	100.03	53.29	1.88
	18	19.8	52	256.0	3.0	785.4	0.72	129.61	43.19	23.09	11.5	0.01	288.63	0.93	1.43	0.52	61.46	143.31	100.32	53.66	1.89
	19	20.1	49	256.0	2.2	786.8	0.72	129.61	59.64	23.53	10.7	0.01	288.52	0.93	1.45	0.52	63.42	141.35	98.95	58.58	2.06
	20	19.3	43	256.0	2.0	787.6	0.72	129.61	66.16	22.39	8.3	0.01	288.19	0.93	1.39	0.52	68.23	136.55	95.58	61.18	2.15
	21	18.8	48	256.0	2.0	787.8	0.72	129.61	64.06	21.70	9.3	0.01	288.32	0.94	1.35	0.52	65.40	139.37	97.56	56.89	2.00
	22	20.1	41	256.0	2.1	787.9	0.72	129.61	61.96	23.53	9	0.01	288.28	0.93	1.45	0.52	67.28	137.49	96.25	62.57	2.20
	23	19.2	40	256.0	1.8	789	0.72	129.61	73.75	22.25	8.5	0.01	288.21	0.94	1.38	0.52	67.65	137.13	95.99	60.71	2.14
	24	19.6	40	256.0	2.6	788.7	0.72	129.61	49.00	22.81	8.7	0.01	288.24	0.93	1.41	0.52	67.54	137.24	96.07	60.56	2.13
	25	19.6	45	256.0	2.3	787.9	0.72	129.61	55.99	22.81	9.7	0.01	288.38	0.93	1.41	0.52	65.20	139.57	97.70	58.57	2.06
	26	19.6	43	256.0	2.0	787.2	0.72	129.61	66.31	22.81	9.3	0.01	288.32	0.93	1.41	0.52	66.12	138.65	97.06	60.16	2.12
	27	18.4	56	256.0	2.3	787.1	0.72	129.61	55.99	21.16	11.4	0.01	288.61	0.93	1.32	0.52	60.50	144.27	100.99	49.50	1.74
	28	16	72	256.0	2.2	787.7	0.72	129.61	59.29	18.18	12.7	0.01	288.79	0.94	1.16	0.52	56.01	148.76	104.13	37.08	1.31
	29	16.2	69	256.0	2.2	788.2	0.72	129.61	58.15	18.42	12.1	0.01	288.71	0.94	1.17	0.52	57.32	147.46	103.22	39.21	1.38
	30	16.9	70	256.0	3.1	788	0.72	129.61	41.42	19.25	12.5	0.01	288.76	0.94	1.22	0.52	57.10	147.68	103.37	37.96	1.34
	31	17.1	65	256.0	2.3	787.3	0.72	129.61	55.99	19.50	11.9	0.01	288.68	0.94	1.23	0.52	58.43	146.35	102.44	42.96	1.51
apr								129.61		6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	19	53	260.4	2.7	786.7	0.67	129.61	47.99	21.97	11.2	0.01	288.59	0.93	1.37	0.52	58.25	150.07	105.05	52.48	1.85
	2	17.1	67	260.4	2.3	786.7	0.67	129.61	55.99	19.50	12.6	0.01	288.78	0.94	1.23	0.52	54.12	154.20	107.94	42.12	1.48
	3	16.2	73	260.4	2.1	787	0.67	129.61	62.60	18.42	12.7	0.01	288.79	0.94	1.17	0.52	53.27	155.06	108.54	39.42	1.39
	4	17.1	67	260.4	1.6	786.9	0.67	129.61	79.57	19.50	12.3	0.01	288.74	0.94	1.23	0.52	54.67	153.65	107.56	46.52	1.64
	5	15.9	77	260.4	2.8	788.2	0.67	129.61	46.52	18.07	13.5	0.01	288.90	0.94	1.15	0.52	51.64	156.68	109.68	32.78	1.15
	6	15.1	82	260.4	2.6	788.3	0.67	129.61	49.57	17.16	13.5	0.01	288.90	0.95	1.10	0.52	51.08	157.25	110.07	30.23	1.06
	7	17.9	70	260.4	2.0	786.7	0.67	129.61	66.45	20.51	13.5	0.01	288.91	0.94	1.29	0.52	53.09	155.24	108.67	44.97	1.58
	8	18	69	260.4	2.4	786.5	0.67	129.61	53.23	20.64	13.8	0.01	288.95	0.93	1.30	0.52	52.63	155.70	108.99	42.27	1.49
	9	18.1	66	260.4	1.3	787.2	0.67	129.61	100.79	20.77	13.2	0.01	288.86	0.94	1.30	0.52	53.77	154.55	108.19	51.12	1.80
	10	18.3	68	260.4	2.0	787.9	0.67	129.61	64.33	21.03	13.7	0.01	288.93	0.94	1.32	0.52	53.02	155.30	108.71	45.77	1.61
	11	17.5	69	260.4	2.1	787.7	0.67	129.61	61.08	20.00	13.1	0.01	288.85	0.94	1.26	0.52	53.51	154.81	108.37	43.37	1.53
	12	16.9	71	260.4	2.3	787.1	0.67	129.61	57.37	19.25	13.1	0.01	288.85	0.94	1.22	0.52	53.07	155.25	108.68	40.25	1.42
	13	15.6	82	260.4	2.1	788.1	0.67	129.61	62.99	17.72	14	0.01	288.97	0.94	1.13	0.52	50.58	157.75	110.42	33.79	1.19
	14	14.5	83	260.4	2.7	789.7	0.67	129.61	47.47	16.51	13.7	0.01	288.93	0.95	1.07	0.52	50.31	158.01	110.61	26.75	0.94
	15	12.3	93	260.4	2.7	790.2	0.67	129.61	48.30	14.31	13.3	0.01	288.87	0.98	0.94	0.52	49.46	158.87	111.21	19.72	0.69
	16	14.1	81	260.4	2.2	789.5	0.67	129.61	58.15	16.09	12.8	0.01	288.80	0.95	1.04	0.52	51.57	156.75	109.73	30.12	1.06
	17	13	81	260.4	2.8	788.3	0.67	129.61	46.52	14.98	12	0.01	288.69	0.96	0.98	0.52	52.18	156.15	109.30	25.79	0.91
	18	14.6	72	260.4	1.7	787.8	0.67	129.61	75.03	16.62	11.6	0.01	288.64	0.95	1.07	0.52	54.08	154.24	107.97	38.14	1.34
	19	13.9	74	260.4	2.6	788.9	0.67	129.61	50.14	15.88	11.4	0.01	288.61	0.95	1.03	0.52	53.92	154.40	108.08	31.66	1.11
	20	16.2	67	260.4	1.5	787.6	0.67	129.61	87.14	18.42	11.8	0.01	288.67	0.94	1.17	0.52	54.92	153.41	107.38	45.24	1.59
	21	18.8	62	260.4	1.8	787	0.67	129.61	79.57	21.70	12.9	0.01	288.82	0.93	1.35	0.52	54.84	153.48	107.44	51.84	1.82
	22	19.1	61	260.4	2.9	786.3	0.67	129.61	44.14	22.11	12.6	0.01	288.78	0.93	1.38	0.52	55.63	152.70	106.88	48.58	1.71
	23	20.3	60	260.4	2.0	786.1	0.67	129.61	66.02	23.82	13.3	0.01	288.88	0.93	1.47	0.52	55.23	153.09	107.17	55.42	1.95
	24	19.9	57	260.4	3.1	785.9	0.67	129.61	41.58	23.24	12.5	0.01	288.77	0.93	1.44	0.52	56.43	151.90	106.33	52.08	1.83
	25	18.8	63	260.4	1.9	785.4	0.67	129.61	69.35	21.70	13.1	0.01	288.85	0.93	1.35	0.52	54.47	153.85	107.69	50.06	1.76
	26	19.6	55	260.4	1.4	785.3	0.67	129.61	95.38	22.81	11.7	0.01	288.66	0.93	1.41	0.52	57.74	150.58	105.41	58.84	2.07
	27	18.8	60	260.4	1.8	785.7	0.67	129.61	73.21	21.70	12.5	0.01	288.77	0.93	1.35	0.52	55.58	152.74	106.92	51.91	1.83
	28	18.6	61	260.4	1.7	785.8	0.67	129.61	77.13	21.43	12.6	0.01	288.78	0.93	1.34	0.52	55.25	153.08	107.15	51.40	1.81
	29	17.7	67	260.4	1.0	785.6	0.67	129.61	123.92	20.25	12.9	0.01	288.83	0.93	1.27	0.52	54.02	154.30	108.01	52.68	1.85
	30	18.3	62	260.4	1.7	785.5	0.67	129.61	76.16	21.03	12	0.01	288.70	0.93	1.32	0.52	56.15	152.18	106.52	51.40	1.81

may								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	20.3	53	276.7	1.4	786.1	0.72	129.61	93.61	23.82	11.7	0.01	288.66	0.93	1.47	0.52	61.46	159.92	111.94	63.68	2.24
	2	20.1	49	276.7	2.6	786.9	0.72	129.61	50.39	23.53	10.7	0.01	288.52	0.93	1.45	0.52	63.42	157.96	110.57	60.35	2.12
	3	18.2	62	276.7	3.0	787.8	0.72	129.61	42.89	20.90	12.8	0.01	288.81	0.94	1.31	0.52	57.54	163.83	114.68	45.06	1.59
	4	19	59	276.7	2.9	786.6	0.72	129.61	44.33	21.97	12	0.01	288.70	0.93	1.37	0.52	59.77	161.61	113.13	51.14	1.80
	5	20.2	55	276.7	1.8	785.5	0.72	129.61	70.81	23.67	11.6	0.01	288.67	0.93	1.46	0.52	61.17	160.21	112.14	60.75	2.14
	6	19.6	58	276.7	2.9	785.4	0.72	129.61	44.27	22.81	12	0.01	288.70	0.93	1.41	0.52	60.26	161.12	112.78	53.86	1.90
	7	19.7	61	276.7	2.3	785.5	0.72	129.61	55.38	22.95	13.2	0.01	288.87	0.93	1.42	0.52	57.95	163.43	114.40	53.19	1.87
	8	21.4	42	276.7	1.7	785.8	0.72	129.61	76.55	25.49	10	0.01	288.42	0.92	1.56	0.52	66.13	155.25	108.67	69.78	2.46
	9	20.1	44	276.7	1.2	787.2	0.72	129.61	107.22	23.53	9.8	0.01	288.39	0.93	1.45	0.52	65.42	155.95	109.17	67.08	2.36
	10	21.1	43	276.7	1.6	785.9	0.72	129.61	83.07	25.02	10.4	0.01	288.48	0.93	1.53	0.52	64.96	156.42	109.49	68.27	2.40
	11	21.8	41	276.7	3.3	785.2	0.72	129.61	39.58	26.12	10.4	0.01	288.48	0.92	1.59	0.52	65.58	155.80	109.06	67.78	2.39
	12	19.6	64	276.7	3.6	785.2	0.72	129.61	36.43	22.81	14.2	0.01	289.01	0.93	1.41	0.52	55.96	165.42	115.79	46.14	1.62
	13	17.6	80	276.7	3.3	787.1	0.72	129.61	38.91	20.13	15	0.01	289.11	0.94	1.27	0.52	53.01	168.37	117.86	35.10	1.24
	14	17.3	75	276.7	3.2	788.6	0.72	129.61	39.94	19.75	13.9	0.01	288.96	0.94	1.25	0.52	54.77	166.60	116.62	37.21	1.31
	15	17.8	64	276.7	1.6	789.4	0.72	129.61	82.84	20.38	13.2	0.01	288.86	0.94	1.28	0.52	56.46	164.92	115.44	49.64	1.75
	16	16.8	76	276.7	2.7	788.6	0.72	129.61	47.99	19.13	14.4	0.01	289.03	0.94	1.21	0.52	53.49	167.88	117.52	35.68	1.26
	17	18.3	67	276.7	2.4	786.6	0.72	129.61	54.97	21.03	13.7	0.01	288.93	0.93	1.32	0.52	55.91	165.47	115.83	45.68	1.61
	18	19.4	56	276.7	1.1	786.6	0.72	129.61	114.53	22.53	11.7	0.01	288.66	0.93	1.40	0.52	60.71	160.67	112.47	62.16	2.19
	19	20.2	49	276.7	1.7	787	0.72	129.61	75.40	23.67	10.2	0.01	288.45	0.93	1.46	0.52	64.61	156.77	109.74	64.46	2.27
	20	20.3	43	276.7	1.6	787	0.72	129.61	80.84	23.82	9.1	0.01	288.30	0.93	1.47	0.52	67.23	154.15	107.91	67.42	2.37
	21	20.6	38	276.7	1.3	786.9	0.72	129.61	99.46	24.27	8.5	0.01	288.21	0.93	1.49	0.52	68.95	152.43	106.70	70.51	2.48
	22	21.1	35	276.7	1.3	786.8	0.72	129.61	101.46	25.02	8.4	0.01	288.20	0.93	1.53	0.52	69.67	151.71	106.20	72.51	2.55
	23	21.3	36	276.7	1.8	787.2	0.72	129.61	73.03	25.33	9.1	0.01	288.30	0.93	1.55	0.52	68.15	153.23	107.26	70.89	2.50
	24	20.8	35	276.7	1.1	786.8	0.72	129.61	114.53	24.57	8.2	0.01	288.17	0.93	1.51	0.52	69.89	151.49	106.04	72.16	2.54
	25	20.1	33	276.7	1.2	786.4	0.72	129.61	104.26	23.53	7.4	0.01	288.06	0.93	1.45	0.52	71.26	150.12	105.08	70.66	2.49
	26	21.2	33	276.7	1.5	786.5	0.72	129.61	86.88	25.18	7.6	0.01	288.12	0.93	1.54	0.52	71.29	150.09	105.06	73.41	2.58
	27	21.9	32	276.7	1.7	787.3	0.72	129.61	77.93	26.28	8.2	0.01	288.17	0.93	1.60	0.52	70.94	150.44	105.31	75.13	2.64
	28	22.6	29	276.7	1.6	787.1	0.72	129.61	80.63	27.42	7.6	0.01	288.09	0.92	1.66	0.52	73.18	148.19	103.74	78.91	2.78
	29	21.4	34	276.7	2.6	786.6	0.72	129.61	49.89	25.49	8.3	0.01	288.19	0.93	1.56	0.52	70.20	151.17	105.82	71.91	2.53
	30	21.7	35	276.7	1.2	785.7	0.72	129.61	111.96	25.96	8.7	0.01	288.24	0.92	1.58	0.52	69.49	151.88	106.32	74.48	2.62
	31	22.6	47	276.7	2.0	785.5	0.72	129.61	64.81	27.42	12.1	0.01	288.71	0.92	1.66	0.52	62.56	158.82	111.17	69.81	2.46
jun								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	22.7	43	257.0	1.7	786.5	0.64	129.61	77.93	27.59	11.5	0.01	288.63	0.92	1.67	0.52	58.66	146.91	102.84	70.01	2.46
	2	23.3	39	257.0	1.4	786	0.64	129.61	91.62	28.61	10.2	0.01	288.45	0.92	1.72	0.52	61.83	143.74	100.62	75.00	2.64
	3	23.1	32	257.0	1.8	784.8	0.64	129.61	72.86	28.26	8.8	0.01	288.26	0.92	1.71	0.52	64.75	140.82	98.57	76.56	2.69
	4	22.9	36	257.0	2.1	784.7	0.64	129.61	62.34	27.92	9.7	0.01	288.38	0.92	1.69	0.52	62.57	143.00	100.10	73.91	2.60
	5	21.8	53	257.0	2.5	785.7	0.64	129.61	50.99	26.12	13.2	0.01	288.87	0.92	1.59	0.52	54.71	150.86	105.60	60.30	2.12
	6	21.8	47	257.0	1.8	785.8	0.64	129.61	70.32	26.12	11.3	0.01	288.60	0.92	1.59	0.52	58.34	147.23	103.06	66.27	2.33
	7	22	37	257.0	1.5	784.8	0.64	129.61	87.90	26.44	9.3	0.01	288.33	0.92	1.61	0.52	62.68	142.89	100.02	71.54	2.52
	8	22.3	33	257.0	1.6	784.2	0.64	129.61	81.50	26.93	8.1	0.01	288.16	0.92	1.63	0.52	65.68	139.89	97.93	74.69	2.63
	9	22.1	29	257.0	2.2	785	0.64	129.61	58.94	26.60	7.3	0.01	288.05	0.92	1.62	0.52	67.43	138.14	96.70	75.60	2.66
	10	22.2	42	257.0	1.7	785.3	0.64	129.61	77.93	26.76	10.9	0.01	288.55	0.92	1.63	0.52	59.47	146.10	102.27	69.12	2.43
	11	22.6	36	257.0	2.1	784.5	0.64	129.61	62.86	27.42	9.6	0.01	288.37	0.92	1.66	0.52	62.53	143.04	100.12	72.85	2.56
	12	22.3	28	257.0	1.9	784.4	0.64	129.61	68.41	26.93	7.1	0.01	288.02	0.92	1.63	0.52	68.12	137.45	96.22	76.66	2.70
	13	22.2	26	257.0	1.7	785.2	0.64	129.61	74.84	26.76	6.5	0.01	287.94	0.92	1.63	0.52	69.57	136.00	95.20	77.24	2.72
	14	22.4	33	257.0	1.7	785.9	0.64	129.61	75.03	27.09	8.7	0.01	288.24	0.92	1.64	0.52	64.37	141.20	98.84	73.96	2.60
	15	23.4	41	257.0	2.1	785.3	0.64	129.61	62.99	28.78	10.8	0.01	288.54	0.92	1.73	0.52	60.65	144.92	101.45	73.80	2.60
	16	23.6	37	257.0	2.8	785.3	0.64	129.61	46.16	29.13	10.1	0.01	288.44	0.92	1.75	0.52	62.29	143.28	100.29	75.96	2.67
	17	24.4	39	257.0	2.3	785.4	0.64	129.61	57.37	30.56	11	0.01	288.56	0.91	1.83	0.52	61.05	144.52	101.16	77.78	2.74
	18	23.6	29	257.0	2.0	785.8	0.64	129.61	64.33	29.13	8	0.01	288.15	0.92	1.75	0.52	67.08	138.49	96.94	80.28	2.83
	19	23.3	36	257.0	2.4	785.7	0.64	129.61	54.58	28.61	9.5	0.01	288.35	0.92	1.72	0.52	63.35	142.22	99.56	76.00	2.68
	20	23.5	31	257.0	2.3	785.3	0.64	129.61	55.99	28.96	9	0.01	288.29	0.92	1.74	0.52	64.64	140.93	98.65	77.99	2.75
	21	22.7	32	257.0	2.2	786.2	0.64	129.61	59.29	27.59	8.7	0.01	288.24	0.92	1.67	0.52	64.63	140.94	98.66	75.12	2.64
	22	21.8	34	257.0	1.4	786.8	0.64	129.61	91.90	26.12	8.9	0.01	288.27	0.92	1.59	0.52	63.40	142.17	99.52	71.53	2.52
	23	21.1	31	257.0	1.5	786	0.64	129.61	84.46	25.02	7.8	0.01	288.12	0.93	1.53	0.52	65.32	140.25	98.17	70.76	2.49
	24	21.5	40	257.0	2.1	786	0.64	129.61	62.34	25.64	10.2	0.01	288.45	0.92	1.57	0.52	60.34	145.23	101.66	66.88	2.36
	25	22	51	257.0	2.0	784.4	0.64	129.61	63.92	26.44	12.5	0.01	288.77	0.92	1.61	0.52	56.17	149.40	104.58	64.15	2.26
	26	22.2	43	257.0	3.1	784.5	0.64	129.61	41.99	26.76	10.8	0.01	288.54	0.92	1.63	0.52	59.67	145.90	102.13	67.37	2.37
	27	23.5	34	257.0	2.8	785.2	0.64	129.61	46.37	28.96	8.9	0.01	288.27	0.92	1.74	0.52	64.87	140.70	98.49	78.35	2.76
	28	23.2	41	257.0	2.5	785.5	0.64	129.61	51.25	28.44	10.7	0.01	288.52	0.92	1.71	0.52	60.69	144.88	101.41	72.77	2.56
	29	24.2	39	257.0	1.8	784.7	0.64	129.61	73.21	30.20	10.5	0.01	288.49	0.91	1.81	0.52	61.94	143.63	100.54	77.95	2.74
	30	24.1	30	257.0	1.7	784.3	0.64	129.61	78.35	30.02	8.1	0.01	288.16	0.92	1.80	0.52	67.29	138.28	96.80	81.71	2.88

jul								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	23.7	25	241.2	1.8	783.7	0.57	129.61	73.75	29.31	7.1	0.01	288.02	0.92	1.78	0.52	63.96	128.99	90.29	80.35	2.83
	2	23.2	29	241.2	1.6	783.7	0.57	129.61	82.61	28.44	7.3	0.01	288.05	0.92	1.71	0.52	63.06	129.89	90.92	77.68	2.73
	3	22.8	23	241.2	1.4	783.7	0.57	129.61	95.38	27.76	6.1	0.00	287.89	0.92	1.68	0.52	65.62	127.33	89.13	77.60	2.73
	4	22.8	30	241.2	3.1	784.3	0.57	129.61	42.29	27.76	7.8	0.01	288.12	0.92	1.68	0.52	61.58	131.38	91.95	76.72	2.70
	5	23.1	36	241.2	3.0	784.2	0.57	129.61	43.82	28.26	9.6	0.01	288.37	0.92	1.71	0.52	58.01	134.94	94.46	73.58	2.59
	6	22.2	42	241.2	2.4	784	0.57	129.61	53.05	26.76	10.8	0.01	288.54	0.92	1.63	0.52	54.98	137.97	96.58	66.68	2.35
	7	23.4	40	241.2	3.3	784.3	0.57	129.61	39.78	28.78	10.4	0.01	288.48	0.92	1.73	0.52	56.65	136.30	95.41	72.97	2.57
	8	23.7	42	241.2	2.7	784.6	0.57	129.61	47.99	29.31	10.7	0.01	288.52	0.92	1.78	0.52	56.29	136.65	95.66	73.70	2.59
	9	23.9	36	241.2	2.1	784	0.57	129.61	61.71	29.66	9.6	0.01	288.37	0.91	1.78	0.52	58.63	134.31	94.02	76.87	2.71
	10	24.5	34	241.2	2.5	783.1	0.57	129.61	52.13	30.75	9.5	0.01	288.36	0.91	1.83	0.52	59.32	133.63	93.54	80.10	2.82
	11	22.5	40	241.2	2.3	783.1	0.57	129.61	55.99	27.26	10.2	0.01	288.46	0.92	1.65	0.52	56.35	136.59	95.62	69.50	2.45
	12	22.6	43	241.2	2.5	784.2	0.57	129.61	51.25	27.42	11.2	0.01	288.59	0.92	1.66	0.52	54.53	138.42	96.89	67.46	2.37
	13	22.9	50	241.2	2.9	784.5	0.57	129.61	44.46	27.92	12.9	0.01	288.83	0.92	1.69	0.52	51.68	141.26	98.88	64.31	2.26
	14	23.2	47	241.2	2.4	783.7	0.57	129.61	54.28	28.44	12.8	0.01	288.82	0.92	1.71	0.52	52.07	140.88	98.61	66.64	2.35
	15	22.8	46	241.2	2.6	783.6	0.57	129.61	50.39	27.76	12.2	0.01	288.73	0.92	1.68	0.52	52.85	140.10	98.07	65.96	2.32
	16	21.3	45	241.2	2.2	783.9	0.57	129.61	59.75	25.33	11.3	0.01	288.61	0.92	1.55	0.52	53.39	139.56	97.69	61.94	2.18
	17	22.6	38	241.2	2.7	783.7	0.57	129.61	47.92	27.42	9.9	0.01	288.41	0.92	1.66	0.52	57.02	135.93	95.15	70.51	2.48
	18	22.8	40	241.2	2.8	783.7	0.57	129.61	46.80	27.76	10.8	0.01	288.54	0.92	1.68	0.52	55.43	137.52	96.26	69.21	2.44
	19	23.4	39	241.2	1.6	783.9	0.57	129.61	78.74	28.78	10.7	0.01	288.52	0.92	1.73	0.52	56.07	136.88	95.81	72.54	2.55
	20	24.5	38	241.2	1.5	784	0.57	129.61	86.88	30.75	10.9	0.01	288.55	0.91	1.83	0.52	56.52	136.43	95.50	76.52	2.69
	21	23	47	241.2	3.3	785	0.57	129.61	39.47	28.09	12.5	0.01	288.77	0.92	1.70	0.52	52.46	140.49	98.34	65.48	2.30
	22	23.3	44	241.2	2.8	785.7	0.57	129.61	46.88	28.61	11.7	0.01	288.66	0.92	1.72	0.52	54.11	138.83	97.18	69.35	2.44
	23	23.7	35	241.2	3.6	784.5	0.57	129.61	36.43	29.31	9.6	0.01	288.37	0.92	1.78	0.52	58.48	134.47	94.13	76.60	2.70
	24	22.4	43	241.2	2.8	783.3	0.57	129.61	45.74	27.09	10.8	0.01	288.54	0.92	1.64	0.52	56.13	137.82	96.47	67.30	2.37
	25	21.3	50	241.2	2.4	783.9	0.57	129.61	53.51	25.33	11.5	0.01	288.63	0.92	1.55	0.52	53.03	139.92	97.94	61.03	2.15
	26	22.8	41	241.2	3.1	784.1	0.57	129.61	42.11	27.76	10.5	0.01	288.50	0.92	1.68	0.52	56.00	138.95	95.86	69.84	2.46
	27	23.4	39	241.2	3.0	784.4	0.57	129.61	43.63	28.78	10.8	0.01	288.54	0.92	1.73	0.52	55.88	137.07	95.95	71.99	2.53
	28	23.3	41	241.2	1.7	784.6	0.57	129.61	75.21	28.61	10.7	0.01	288.52	0.92	1.72	0.52	55.99	136.95	95.87	72.10	2.54
	29	22.6	50	241.2	2.9	785.8	0.57	129.61	45.40	27.42	12.8	0.01	288.81	0.92	1.66	0.52	51.65	141.30	98.91	63.17	2.22
	30	21.9	51	241.2	2.9	785.2	0.57	129.61	44.79	26.28	12.4	0.01	288.76	0.92	1.60	0.52	51.66	141.09	98.76	60.81	2.14
	31	22.5	43	241.2	2.0	784.2	0.57	129.61	64.33	27.26	10.7	0.01	288.52	0.92	1.65	0.52	55.39	137.58	96.29	68.59	2.41
aug								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	23.6	36	240.4	1.6	783.6	0.58	129.61	82.61	29.13	9.4	0.01	288.34	0.92	1.75	0.52	59.52	132.78	92.94	75.28	2.65
	2	24.4	27	240.4	1.9	784.4	0.58	129.61	67.19	30.58	7.2	0.01	288.04	0.91	1.83	0.52	65.11	127.19	89.03	83.07	2.92
	3	25.2	23	240.4	2.8	783.9	0.58	129.61	46.37	32.06	7	0.01	288.01	0.91	1.90	0.52	66.30	126.00	88.20	89.20	3.14
	4	22.3	45	240.4	2.6	784.7	0.58	129.61	50.73	26.93	11.7	0.01	288.66	0.92	1.63	0.52	54.04	138.26	96.78	64.64	2.28
	5	22.8	45	240.4	2.8	784.2	0.58	129.61	47.10	27.76	11.7	0.01	288.66	0.92	1.68	0.52	54.41	137.89	96.53	66.78	2.35
	6	23.9	32	240.4	1.9	783.9	0.58	129.61	86.75	29.66	8.4	0.01	288.20	0.92	1.78	0.52	61.91	130.38	91.27	78.80	2.77
	7	24.2	25	240.4	2.6	783.9	0.58	129.61	49.16	30.20	7.4	0.01	288.07	0.91	1.81	0.52	64.46	127.84	89.49	83.38	2.94
	8	20.9	57	240.4	2.0	785.4	0.58	129.61	86.45	24.72	13.5	0.01	288.91	0.92	1.52	0.52	49.90	142.40	99.68	55.59	1.98
	9	19.2	69	240.4	3.0	786.4	0.58	129.61	43.82	22.25	14.7	0.01	289.07	0.93	1.38	0.52	46.83	145.47	101.83	41.79	1.47
	10	21.2	64	240.4	3.6	786.3	0.58	129.61	36.34	25.18	14.8	0.01	289.09	0.92	1.54	0.52	47.97	144.33	101.03	40.64	1.75
	11	23.3	55	240.4	2.0	785.5	0.58	129.61	66.73	28.61	14	0.01	288.98	0.92	1.72	0.52	50.69	141.61	99.13	64.91	2.28
	12	22.5	50	240.4	2.7	784.7	0.58	129.61	47.84	27.28	12.5	0.01	288.77	0.92	1.65	0.52	52.74	139.56	97.69	63.43	2.23
	13	21.9	53	240.4	2.6	784.4	0.58	129.61	50.65	26.28	12.7	0.01	288.80	0.92	1.60	0.52	51.96	140.34	98.24	60.37	2.13
	14	20.7	54	240.4	3.9	786	0.58	129.61	33.23	24.42	12.5	0.01	288.77	0.93	1.50	0.52	51.47	140.83	98.58	53.31	1.88
	15	21.9	48	240.4	2.4	786.7	0.58	129.61	53.51	26.28	12	0.01	288.70	0.92	1.60	0.52	53.20	139.10	97.37	62.28	2.19
	16	22.8	43	240.4	2.6	785.5	0.58	129.61	50.23	27.76	10.8	0.01	288.53	0.92	1.68	0.52	56.10	136.20	95.34	69.06	2.43
	17	22.7	37	240.4	1.9	785.2	0.58	129.61	67.19	27.59	9.5	0.01	288.36	0.92	1.67	0.52	58.60	133.70	93.59	71.68	2.52
	18	23.1	35	240.4	1.3	785.8	0.58	129.61	96.29	28.26	8.7	0.01	288.24	0.92	1.71	0.52	60.60	131.70	92.19	74.31	2.62
	19	23.5	28	240.4	1.6	786.2	0.58	129.61	80.84	28.96	7.8	0.01	288.12	0.92	1.74	0.52	62.93	129.37	90.56	77.67	2.73
	20	24	24	240.4	2.3	786	0.58	129.61	57.05	29.84	7.2	0.01	288.04	0.92	1.79	0.52	64.76	127.54	89.28	82.25	2.90
	21	24.1	24	240.4	1.4	785.4	0.58	129.61	95.38	30.02	6.9	0.01	288.00	0.92	1.80	0.52	65.57	126.73	88.71	80.48	2.83
	22	23.4	35	240.4	1.9	785.6	0.58	129.61	68.10	28.78	8.8	0.01	288.26	0.92	1.73	0.52	60.63	131.67	92.17	75.92	2.67
	23	23.2	31	240.4	2.7	785.7	0.58	129.61	47.30	28.44	8.3	0.01	288.19	0.92	1.71	0.52	61.56	130.75	91.52	76.87	2.71
	24	23.5	40	240.4	1.8	785.4	0.58	129.61	72.51	28.96	10.6	0.01	288.51	0.92	1.74	0.52	57.02	135.28	94.69	72.79	2.56
	25	22.5	49	240.4	2.7	784.1	0.58	129.61	47.17	27.28	12.7	0.01	288.80	0.92	1.66	0.52	52.38	139.92	97.94	62.69	2.21
	26	21.7	51	240.4	2.9	783.9	0.58	129.61	44.60	25.96	12	0.01	288.70	0.92	1.58	0.52	53.06	139.24	97.47	60.70	2.14
	27	20.6	54	240.4	2.8	784.2	0.58	129.61	49.16	24.27	11.7	0.01	288.66	0.92	1.49	0.52	52.81	139.49	97.64	56.86	2.00
	28	20.8	49	240.4	2.6	785.8	0.58	129.61	49.32	24.57	11.3	0.01	288.60	0.93	1.51	0.52	53.68	138.62	97.04	58.75	2.07
	29	22.9	44	240.4	1.9	784.4	0.58	129.61	67.19	27.92	11.6	0.01	288.65	0.92	1.69	0.52	54.68	137.63	96.34	68.23	2.40
	30	23.5	34	240.4	1.9	784.1	0.58	129.61	69.19	28.96	9.4	0.01	288.34	0.92	1.74	0.52	59.44	132.86	93.00	75.14	2.64
	31	24.4	28	240.4	1.9	784.9	0.58	129.61	68.72	30.56	8.4	0.01	288.20	0.91	1.83	0.52	62.33	129.97	90.98	80.73	2.84

sep								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	20.7	24	250.5	0.8	785.1	0.67	129.61	156.65	24.42	7.1	0.01	288.02	0.93	1.50	0.52	68.90	131.46	92.02	68.80	2.42
	2	20.7	26	250.5	1.7	784.4	0.67	129.61	74.10	24.42	6.8	0.01	287.98	0.93	1.50	0.52	69.68	130.69	91.48	69.54	2.45
	3	20.7	25	250.5	1.7	783.7	0.67	129.61	77.72	24.42	6.7	0.01	287.97	0.93	1.50	0.52	69.94	130.43	91.30	69.71	2.45
	4	20.7	38	250.5	2.5	784.2	0.67	129.61	52.13	24.42	10	0.01	288.43	0.92	1.50	0.52	62.13	138.24	96.76	62.08	2.19
	5	20.7	39	250.5	1.7	785.3	0.67	129.61	74.65	24.42	9.3	0.01	288.33	0.93	1.50	0.52	63.66	136.70	95.69	64.64	2.28
	6	20.7	22	250.5	2.0	785.9	0.67	129.61	65.16	24.42	6.6	0.01	287.95	0.93	1.50	0.52	70.20	130.16	91.11	70.02	2.46
	7	20.7	26	250.5	2.0	785.8	0.67	129.61	84.33	24.42	6.1	0.00	287.88	0.93	1.50	0.52	71.55	128.81	90.17	71.08	2.50
	8	20.7	26	250.5	1.9	785.1	0.67	129.61	67.34	24.42	6.6	0.01	287.95	0.93	1.50	0.52	70.20	130.16	91.11	70.00	2.46
	9	20.7	27	250.5	1.8	785.6	0.67	129.61	71.98	24.42	6.9	0.01	287.99	0.93	1.50	0.52	69.42	130.95	91.66	69.35	2.44
	10	20.7	30	250.5	1.7	786.3	0.67	129.61	76.93	24.42	7.1	0.01	288.02	0.93	1.50	0.52	68.90	131.46	92.02	68.94	2.43
	11	20.7	25	250.5	1.4	786.8	0.67	129.61	89.71	24.42	6.2	0.00	287.90	0.93	1.50	0.52	71.28	129.09	90.36	70.41	2.48
	12	20.7	29	250.5	1.6	786.3	0.67	129.61	79.77	24.42	7	0.01	288.01	0.93	1.50	0.52	69.16	131.21	91.84	69.12	2.43
	13	20.7	25	250.5	1.9	786	0.67	129.61	68.71	24.42	6.4	0.01	287.93	0.93	1.50	0.52	70.73	129.63	90.74	70.38	2.48
	14	20.7	23	250.5	1.5	785.9	0.67	129.61	88.66	24.42	5.6	0.00	287.81	0.93	1.50	0.52	72.96	127.40	89.18	71.42	2.51
	15	20.7	23	250.5	1.8	786.2	0.67	129.61	73.20	24.42	5.4	0.00	287.79	0.93	1.50	0.52	73.54	126.82	88.78	72.22	2.54
	16	20.7	23	250.5	1.6	786.3	0.67	129.61	80.20	24.42	5.5	0.00	287.80	0.93	1.50	0.52	73.25	127.12	88.98	71.82	2.53
	17	20.7	24	250.5	2.1	785.8	0.67	129.61	62.99	24.42	5.7	0.00	287.83	0.93	1.50	0.52	72.67	127.69	89.38	71.95	2.53
	18	20.7	30	250.5	2.4	785.1	0.67	129.61	53.23	24.42	8.5	0.01	288.22	0.93	1.50	0.52	65.49	134.88	94.41	65.72	2.31
	19	20.7	43	250.5	2.7	785.2	0.67	129.61	47.99	24.42	10.3	0.01	288.47	0.93	1.50	0.52	61.49	138.88	97.21	61.07	2.15
	20	20.7	36	250.5	2.2	785.7	0.67	129.61	59.51	24.42	8.4	0.01	288.20	0.93	1.50	0.52	65.72	134.64	94.25	66.10	2.33
	21	20.7	34	250.5	1.7	785.9	0.67	129.61	76.93	24.42	7.9	0.01	288.13	0.93	1.50	0.52	66.91	133.45	93.42	67.42	2.37
	22	20.7	31	250.5	1.9	785.7	0.67	129.61	66.74	24.42	6.9	0.01	287.99	0.93	1.50	0.52	69.42	130.95	91.66	69.39	2.44
	23	20.7	29	250.5	1.6	785.8	0.67	129.61	79.35	24.42	6.5	0.01	287.94	0.93	1.50	0.52	70.47	129.90	90.93	70.04	2.47
	24	20.7	33	250.5	2.1	786.3	0.67	129.61	60.95	24.42	7.5	0.01	288.08	0.93	1.50	0.52	67.89	132.47	92.73	68.11	2.40
	25	20.7	33	250.5	1.9	785.9	0.67	129.61	69.82	24.42	7.6	0.01	288.09	0.93	1.50	0.52	67.65	132.72	92.90	67.95	2.39
	26	20.7	31	250.5	2.4	785.9	0.67	129.61	55.07	24.42	7	0.01	288.01	0.93	1.50	0.52	69.16	131.21	91.84	69.24	2.44
	27	20.7	26	250.5	2.3	785.5	0.67	129.61	57.04	24.42	5.6	0.00	287.82	0.93	1.50	0.52	72.96	127.40	89.18	72.36	2.55
	28	20.7	27	250.5	1.5	785.2	0.67	129.61	85.65	24.42	5.9	0.00	287.86	0.93	1.50	0.52	72.11	128.26	89.78	71.00	2.50
	29	20.7	27	250.5	1.4	785	0.67	129.61	93.31	24.42	6.2	0.00	287.90	0.93	1.50	0.52	71.28	129.09	90.36	70.37	2.48
	30	20.7	34	250.5	1.8	786.4	0.67	129.61	72.50	24.42	8.2	0.01	288.17	0.93	1.50	0.52	66.19	134.17	93.92	66.77	2.35
oct								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	17.1	31	250.1	2.1	787.7	0.76	129.61	61.71	19.50	7.4	0.01	288.06	0.94	1.23	0.52	71.21	128.85	90.19	53.59	1.89
	2	17.1	26	250.1	1.4	787.4	0.76	129.61	93.32	19.50	5.8	0.00	287.84	0.94	1.23	0.52	75.66	124.41	87.09	57.91	2.04
	3	17.1	27	250.1	1.6	786.7	0.76	129.61	81.72	19.50	5.5	0.00	287.80	0.94	1.23	0.52	76.55	123.51	86.46	58.32	2.05
	4	17.1	31	250.1	2.5	787.6	0.76	129.61	51.69	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	126.69	88.69	55.11	1.94
	5	17.1	32	250.1	2.2	788.3	0.76	129.61	57.92	19.50	6.8	0.01	287.98	0.94	1.23	0.52	72.81	127.24	89.07	54.85	1.93
	6	17.1	34	250.1	1.8	788.2	0.76	129.61	72.51	19.50	6.8	0.01	287.98	0.94	1.23	0.52	72.81	127.24	89.07	56.41	1.95
	7	17.1	31	250.1	2.1	789.1	0.76	129.61	62.21	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	125.86	88.10	56.19	1.98
	8	17.1	32	250.1	1.3	788.1	0.76	129.61	98.49	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	126.69	88.69	56.58	1.99
	9	17.1	34	250.1	1.4	789.1	0.76	129.61	91.36	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	125.86	88.10	56.94	2.00
	10	17.1	33	250.1	2.1	789	0.76	129.61	61.96	19.50	7.1	0.01	288.02	0.94	1.23	0.52	72.00	128.05	89.64	54.30	1.91
	11	17.1	41	250.1	1.6	788.2	0.76	129.61	81.72	19.50	6.4	0.01	287.92	0.94	1.23	0.52	73.92	126.14	88.30	56.52	1.99
	12	17.1	37	250.1	1.4	788	0.76	129.61	92.18	19.50	7.4	0.01	288.06	0.94	1.23	0.52	71.21	128.85	90.19	54.92	1.93
	13	17.1	34	250.1	2.0	788.9	0.76	129.61	65.59	19.50	7.2	0.01	288.03	0.94	1.23	0.52	71.74	128.32	89.82	54.23	1.91
	14	17.1	32	250.1	1.5	788.6	0.76	129.61	85.90	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	126.69	88.69	56.24	1.98
	15	17.1	37	250.1	1.5	788.3	0.76	129.61	86.14	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	125.86	88.10	56.83	2.00
	16	17.1	37	250.1	1.6	788.7	0.76	129.61	79.99	19.50	7.1	0.01	288.02	0.94	1.23	0.52	72.00	128.05	89.64	55.04	1.94
	17	17.1	50	250.1	1.5	788.6	0.76	129.61	85.17	19.50	7	0.01	288.00	0.94	1.23	0.52	72.27	127.79	89.45	55.43	1.95
	18	17.1	68	250.1	1.1	788.6	0.76	129.61	120.46	19.50	10.3	0.01	288.46	0.94	1.23	0.52	64.26	135.80	95.06	51.26	1.81
	19	17.1	42	250.1	1.5	788.3	0.76	129.61	87.90	19.50	12.8	0.01	288.81	0.94	1.23	0.52	59.02	141.04	98.73	43.90	1.55
	20	17.1	42	250.1	1.5	788.3	0.76	129.61	86.67	19.50	7.7	0.01	288.10	0.94	1.23	0.52	70.43	129.62	90.74	54.20	1.91
	21	17.1	35	250.1	1.7	788.3	0.76	129.61	74.29	19.50	6.5	0.01	287.94	0.94	1.23	0.52	73.64	126.42	88.49	56.11	1.98
	22	17.1	38	250.1	2.0	788.8	0.76	129.61	83.30	19.50	7.8	0.01	288.11	0.94	1.23	0.52	70.18	129.88	90.91	52.72	1.86
	23	17.1	51	250.1	1.6	788.4	0.76	129.61	81.06	19.50	10.6	0.01	288.50	0.94	1.23	0.52	63.60	136.46	95.52	47.79	1.69
	24	17.1	57	250.1	1.9	787.8	0.76	129.61	88.41	19.50	11.2	0.01	288.58	0.94	1.23	0.52	62.30	137.76	96.43	45.19	1.59
	25	17.1	35	250.1	2.0	787.9	0.76	129.61	64.61	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	126.69	88.69	55.58	1.96
	26	17.1	34	250.1	2.0	788.1	0.76	129.61	64.47	19.50	6.2	0.00	287.90	0.94	1.23	0.52	74.49	125.57	87.90	56.50	1.99
	27	17.1	33	250.1	1.9	787.9	0.76	129.61	67.04	19.50	6.2	0.00	287.90	0.94	1.23	0.52	74.49	125.57	87.90	56.57	1.99
	28	17.1	37	250.1	1.6	788.1	0.76	129.61	83.29	19.50	7.6	0.01	288.09	0.94	1.23	0.52	70.69	129.36	90.56	54.17	1.91
	29	17.1	44	250.1	1.9	788.9	0.76	129.61	87.79	19.50	9.2	0.01	288.31	0.94	1.23	0.52	66.78	133.29	93.31	49.75	1.76
	30	17.1	46	250.1	1.2	789.4	0.76	129.61	106.84	19.50	9.1	0.01	288.29	0.94	1.23	0.52	67.00	133.06	93.14	52.50	1.85
	31	17.1	51	250.1	1.4	789.4	0.76	129.61	94.78	19.50	10.2	0.01	288.44	0.94	1.23	0.52	64.46	135.58	94.91	49.71	1.75

nov								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	14.6	40	244.5	2.5	789.1	0.88	129.61	52.31	16.62	7.9	0.01	288.13	0.95	1.07	0.52	75.57	120.06	84.04	41.12	1.45
	2	14.6	37	244.5	1.5	789.3	0.88	129.61	84.45	16.62	6.6	0.01	287.95	0.95	1.07	0.52	79.29	116.35	81.44	46.01	1.62
	3	14.6	35	244.5	1.4	788.9	0.88	129.61	94.48	16.62	6.1	0.00	287.88	0.95	1.07	0.52	80.81	114.82	80.37	47.35	1.67
	4	14.6	36	244.5	1.2	788.3	0.88	129.61	104.61	16.62	5.9	0.00	287.85	0.95	1.07	0.52	81.44	114.19	79.93	47.99	1.69
	5	14.6	32	244.5	1.7	787.9	0.88	129.61	76.93	16.62	5.1	0.00	287.74	0.95	1.07	0.52	84.06	111.57	78.10	49.01	1.73
	6	14.6	39	244.5	2.0	787.5	0.88	129.61	65.30	16.62	6.6	0.01	287.95	0.95	1.07	0.52	79.29	116.35	81.44	45.24	1.59
	7	14.6	50	244.5	1.7	788.2	0.88	129.61	75.58	16.62	8.8	0.01	288.25	0.95	1.07	0.52	73.18	122.45	85.72	40.69	1.43
	8	14.6	49	244.5	1.6	788.3	0.88	129.61	73.20	16.62	8.5	0.01	288.21	0.95	1.07	0.52	73.96	121.67	85.17	41.21	1.45
	9	14.6	38	244.5	1.4	787.8	0.88	129.61	91.62	16.62	7.5	0.01	288.07	0.95	1.07	0.52	76.68	118.95	83.27	44.49	1.57
	10	14.6	40	244.5	1.7	787.4	0.88	129.61	78.33	16.62	6.9	0.01	287.99	0.95	1.07	0.52	78.40	117.23	82.06	45.14	1.59
	11	14.6	36	244.5	1.6	787.8	0.88	129.61	80.20	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	113.87	79.71	47.58	1.67
	12	14.6	30	244.5	1.4	787.7	0.88	129.61	90.79	16.62	6.3	0.00	287.91	0.95	1.07	0.52	80.20	115.44	80.81	46.87	1.65
	13	14.6	31	244.5	1.4	786.7	0.88	129.61	91.62	16.62	4.9	0.00	287.72	0.95	1.07	0.52	84.75	110.88	77.62	49.62	1.75
	14	14.6	36	244.5	1.5	786.7	0.88	129.61	84.45	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	113.87	79.71	47.70	1.68
	15	14.6	42	244.5	1.5	787.1	0.88	129.61	87.13	16.62	6.8	0.01	287.98	0.95	1.07	0.52	78.69	116.94	81.86	45.73	1.61
	16	14.6	43	244.5	1.4	786.8	0.88	129.61	90.79	16.62	7.1	0.01	288.02	0.95	1.07	0.52	77.82	117.81	82.47	45.27	1.59
	17	14.6	42	244.5	2.1	787.4	0.88	129.61	62.47	16.62	7	0.01	288.01	0.95	1.07	0.52	78.11	117.52	82.27	44.12	1.55
	18	14.6	40	244.5	1.9	788.3	0.88	129.61	69.99	16.62	6.1	0.00	287.88	0.95	1.07	0.52	80.81	114.82	80.37	46.60	1.64
	19	14.6	40	244.5	1.6	788.6	0.88	129.61	81.93	16.62	6.2	0.00	287.89	0.95	1.07	0.52	80.50	115.13	80.59	46.78	1.65
	20	14.6	42	244.5	1.4	788.6	0.88	129.61	94.48	16.62	6.3	0.00	287.91	0.95	1.07	0.52	80.20	115.44	80.81	46.97	1.65
	21	14.6	42	244.5	1.6	788.7	0.88	129.61	81.27	16.62	5.7	0.00	287.83	0.95	1.07	0.52	82.08	113.55	79.49	47.61	1.68
	22	14.6	34	244.5	1.6	787.9	0.88	129.61	80.62	16.62	4.6	0.00	287.67	0.95	1.07	0.52	85.81	109.82	76.88	50.10	1.76
	23	14.6	33	244.5	1.6	787	0.88	129.61	81.71	16.62	4.5	0.00	287.66	0.95	1.07	0.52	86.17	109.46	76.62	50.32	1.77
	24	14.6	34	244.5	1.6	787.7	0.88	129.61	71.81	16.62	5	0.00	287.73	0.95	1.07	0.52	84.41	111.23	77.86	49.15	1.73
	25	14.6	37	244.5	1.6	788.3	0.88	129.61	83.06	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	113.87	79.71	47.65	1.68
	26	14.6	39	244.5	1.7	788.6	0.88	129.61	76.73	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	113.87	79.71	47.48	1.67
	27	14.6	36	244.5	2.0	788.3	0.88	129.61	66.16	16.62	5.4	0.00	287.78	0.95	1.07	0.52	83.06	112.58	78.80	48.12	1.69
	28	14.6	33	244.5	1.5	788.2	0.88	129.61	83.98	16.62	4.6	0.00	287.70	0.95	1.07	0.52	85.10	110.53	77.37	49.72	1.75
	29	14.6	32	244.5	2.0	788.7	0.88	129.61	65.30	16.62	4.2	0.00	287.62	0.95	1.07	0.52	87.28	108.36	75.85	50.90	1.79
	30	14.6	37	244.5	1.6	789.2	0.88	129.61	79.98	16.62	4.7	0.00	287.60	0.95	1.07	0.52	85.45	110.18	77.13	49.88	1.78
dec								129.61	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	12.1	49	223.9	1.9	788.8	0.85	129.61	68.72	14.12	6.2	0.00	287.89	0.96	0.93	0.52	75.68	103.45	72.42	36.77	1.29
	2	12.7	38	223.9	1.6	787.9	0.85	129.61	83.07	14.69	4.8	0.00	287.70	0.96	0.98	0.52	80.68	98.46	68.92	42.11	1.48
	3	13.2	34	223.9	1.3	787.4	0.85	129.61	98.81	15.17	4.3	0.00	287.63	0.96	0.99	0.52	82.96	96.17	67.32	44.50	1.57
	4	13	31	223.9	1.7	787.5	0.85	129.61	77.53	14.98	4.1	0.00	287.61	0.96	0.98	0.52	83.45	95.69	66.98	44.43	1.56
	5	14	28	223.9	1.7	786.7	0.85	129.61	78.13	15.99	4	0.00	287.59	0.95	1.04	0.52	84.99	94.15	65.90	47.37	1.67
	6	14.1	33	223.9	1.1	788.3	0.85	129.61	114.97	16.09	4.5	0.00	287.66	0.95	1.04	0.52	83.30	95.83	67.08	46.31	1.63
	7	13.7	29	223.9	1.7	789.2	0.85	129.61	77.53	15.68	4.2	0.00	287.62	0.96	1.02	0.52	83.90	95.23	66.66	46.11	1.62
	8	14.3	30	223.9	1.6	788.6	0.85	129.61	83.29	16.30	4.3	0.00	287.63	0.95	1.05	0.52	84.24	94.89	66.42	47.48	1.67
	9	13.7	34	223.9	1.8	789.2	0.85	129.61	73.03	15.68	5.1	0.00	287.74	0.96	1.02	0.52	80.81	98.32	68.82	44.10	1.55
	10	12.1	34	223.9	1.1	789	0.85	129.61	118.57	14.12	4.6	0.00	287.67	0.96	0.93	0.52	80.67	98.46	68.92	41.38	1.46
	11	12	40	223.9	1.7	788.3	0.85	129.61	77.13	14.03	5.2	0.00	287.78	0.96	0.92	0.52	78.60	100.53	70.37	39.20	1.38
	12	10	44	223.9	1.8	787.6	0.85	129.61	70.64	12.26	5.1	0.00	287.74	0.97	0.82	0.52	76.73	102.41	71.68	33.91	1.19
	13	12	37	223.9	1.3	786.6	0.85	129.61	99.13	14.03	4.4	0.00	287.65	0.96	0.92	0.52	81.24	97.90	68.53	41.32	1.45
	14	13.4	34	223.9	1.4	787.6	0.85	129.61	92.46	15.37	5.1	0.00	287.74	0.95	1.00	0.52	80.48	98.66	69.06	43.43	1.53
	15	14.2	34	223.9	1.6	788.4	0.85	129.61	73.75	16.19	5.3	0.00	287.77	0.95	1.06	0.52	80.73	98.41	68.88	45.09	1.59
	16	13.2	39	223.9	1.7	788.7	0.85	129.61	75.97	15.17	5.6	0.00	287.81	0.96	0.99	0.52	78.67	100.47	70.33	41.57	1.46
	17	12.7	43	223.9	1.6	789.8	0.85	129.61	72.68	14.69	6.3	0.00	287.91	0.96	0.96	0.52	76.03	103.11	72.17	38.39	1.36
	18	12.1	49	223.9	1.9	790.7	0.85	129.61	89.51	14.12	6.6	0.01	287.95	0.96	0.93	0.52	74.54	104.60	73.22	35.78	1.26
	19	10.6	43	223.9	1.7	789.8	0.85	129.61	78.94	12.78	5.2	0.00	287.76	0.97	0.85	0.52	77.07	102.07	71.45	35.45	1.25
	20	10.8	37	223.9	1.5	788.2	0.85	129.61	88.15	12.78	4.4	0.00	287.65	0.97	0.85	0.52	79.66	99.48	69.64	37.66	1.33
	21	12.5	40	223.9	1.3	787.4	0.85	129.61	102.15	14.49	5.7	0.00	287.83	0.96	0.95	0.52	77.59	101.54	71.08	40.04	1.41
	22	14.5	38	223.9	2.3	788.1	0.85	129.61	55.68	16.51	6	0.00	287.87	0.95	1.07	0.52	78.86	100.27	70.19	44.15	1.56
	23	15.5	40	223.9	1.6	788.3	0.85	129.61	79.99	17.61	6.8	0.01	287.98	0.95	1.13	0.52	77.57	101.56	71.10	45.71	1.61
	24	16	45	223.9	1.6	788.1	0.85	129.61	81.72	18.18	7.8	0.01	288.12	0.95	1.16	0.52	75.28	103.85	72.70	45.17	1.59
	25	15.5	47	223.9	2.0	788.6	0.85	129.61	63.39	17.61	7.9	0.01	288.13	0.95	1.13	0.52	74.49	104.64	73.25	42.81	1.51
	26	14.8	55	223.9	2.0	791.3	0.85	129.61	65.73	16.84	9	0.01	288.28	0.95	1.08	0.52	70.93	108.20	75.74	37.91	1.33
	27	13	58	223.9	1.9	790.9	0.85	129.61	69.63	14.98	8.3	0.01	288.18	0.96	0.98	0.52	70.92	108.21	75.75	34.21	1.20
	28	13.3	46	223.9	1.8	788.6	0.85	129.61	72.33	15.27	6.2	0.00	287.89	0.96	0.99	0.52	76.96	102.17	71.52	40.37	1.42
	29	12.2	38	223.9	1.2	788.8	0.85	129.61	109.55	14.21	4.8	0.00	287.70	0.96	0.93	0.52	80.11	99.02	69.31	41.14	1.45
	30	11.4	27	223.9	1.6	789.8	0.85	129.61	82.16	13.48	3.2	0.00	287.48	0.96	0.89	0.52	84.97	94.16	65.91	42.25	1.49
	31	11.1	32	223.9	2.3	790.2	0.85	129.61	57.05	13.21	3.7	0.00	287.55	0.97	0.88	0.52	82.70	96.44	67.51	40.17	1.41

	1993	mean temp mean °C	rh %	radiation Langley	wind speed m/s	pressure mb	sunshine fraction	Aerodynamic Resistance (ln((z-d)/zo)	ra m/s (2/f2	e*	ea measured	spec humd kgwater/kg	moist air j/kg/k	air density kg/m3	gradient mb/C	psychrom mb/k	Rn w/m2	Rn** W/m2	Rn-G W/m2	final P-M equ	actual evap mm
jan	1	15.6	47	233.3	2.1	790	0.86	56.09	26.22	17.72	7.9	0.01	288.13	0.95	1.13	0.52	75.27	99.69	69.78	36.43	1.28
	2	15.9	42	233.3	1.7	789.3	0.86	56.09	33.55	18.07	7.1	0.01	288.02	0.95	1.15	0.52	77.83	97.13	67.99	40.03	1.41
	3	16.6	48	233.3	2.5	788.2	0.86	56.09	22.56	18.89	8.5	0.01	288.21	0.94	1.20	0.52	74.69	100.27	70.19	38.04	1.34
	4	16.4	42	233.3	1.5	787.1	0.86	56.09	36.35	18.65	7.3	0.01	288.05	0.94	1.19	0.52	77.80	97.17	68.02	41.28	1.45
	5	16	32	233.3	1.3	786.3	0.86	56.09	42.21	18.18	4.9	0.00	287.72	0.94	1.16	0.52	84.88	90.08	63.06	46.13	1.62
	6	15	27	233.3	1.7	788.7	0.86	56.09	33.99	17.05	4.2	0.00	287.62	0.95	1.10	0.52	86.21	88.76	62.13	44.90	1.58
	7	14.7	31	233.3	1.3	788.5	0.86	56.09	42.21	16.73	4.6	0.00	287.67	0.95	1.08	0.52	84.41	90.56	63.39	42.89	1.51
	8	16	33	233.3	1.5	787.1	0.86	56.09	37.39	18.18	4.9	0.00	287.72	0.95	1.16	0.52	84.88	90.08	63.06	46.19	1.63
	9	16.3	38	233.3	1.5	787.5	0.86	56.09	37.39	18.53	6	0.00	287.87	0.94	1.18	0.52	81.59	93.38	65.36	44.34	1.56
	10	15.5	39	233.3	1.7	787.3	0.86	56.09	32.71	17.61	5.7	0.00	287.83	0.95	1.13	0.52	81.64	93.32	65.33	42.47	1.50
	11	15.3	49	233.3	1.6	786.6	0.86	56.09	35.65	17.39	7.2	0.01	288.04	0.95	1.11	0.52	76.90	98.06	68.64	37.87	1.33
	12	15.8	48	233.3	1.4	785.9	0.86	56.09	38.71	17.95	8.3	0.01	288.19	0.94	1.15	0.52	74.40	100.56	70.39	36.78	1.29
	13	15.8	58	233.3	2.2	787.3	0.86	56.09	25.66	17.95	10.1	0.01	288.43	0.94	1.15	0.52	69.84	105.12	73.59	30.77	1.08
	14	12.5	68	233.3	1.6	787.3	0.86	56.09	34.89	14.49	9.7	0.01	288.38	0.96	0.95	0.52	67.64	107.32	75.13	22.09	0.78
	15	11.5	70	233.3	1.7	786.5	0.86	56.09	32.55	13.57	8	0.01	288.15	0.96	0.90	0.52	70.83	104.13	72.89	23.74	0.84
	16	12.1	60	233.3	1.6	786.9	0.86	56.09	35.46	14.12	7.9	0.01	288.13	0.96	0.93	0.52	71.69	103.27	72.29	26.05	0.92
	17	12.8	52	233.3	1.1	787.4	0.86	56.09	50.33	14.78	7.4	0.01	288.06	0.96	0.97	0.52	73.73	101.24	70.87	30.58	1.08
	18	12.4	41	233.3	1.1	787.2	0.86	56.09	52.34	14.40	5.6	0.00	287.81	0.96	0.94	0.52	78.50	96.47	67.53	34.08	1.20
	19	14	44	233.3	2.7	787.1	0.86	56.09	20.67	15.99	6.7	0.01	287.97	0.95	1.04	0.52	76.95	98.02	68.61	34.28	1.21
	20	13.9	43	233.3	1.3	787.5	0.86	56.09	42.21	15.88	6.1	0.00	287.88	0.95	1.03	0.52	78.61	96.35	67.45	36.68	1.29
	21	14.2	49	233.3	2.5	787.5	0.86	56.09	22.41	16.19	7.7	0.01	288.10	0.95	1.05	0.52	74.36	100.60	70.42	32.03	1.13
	22	14.7	60	233.3	1.7	788.4	0.86	56.09	33.13	16.73	9.7	0.01	288.38	0.96	1.08	0.52	69.75	105.22	73.65	28.89	1.02
	23	15.3	61	233.3	1.9	788.4	0.86	56.09	29.01	17.39	10.4	0.01	288.47	0.95	1.11	0.52	68.65	106.32	74.42	28.51	1.00
	24	14.7	62	233.3	1.5	787	0.86	56.09	37.71	16.73	10.3	0.01	288.46	0.95	1.08	0.52	68.31	106.65	74.66	27.74	0.98
	25	13.3	71	233.3	1.6	786.8	0.86	56.09	35.36	15.27	10.6	0.01	288.50	0.95	0.99	0.52	66.31	108.66	76.06	22.11	0.78
	26	12.1	74	233.3	1.8	788.8	0.86	56.09	31.91	14.12	10.7	0.01	288.51	0.96	0.93	0.52	64.98	109.99	76.99	17.60	0.62
	27	13.4	67	233.3	1.0	790.1	0.86	56.09	54.52	15.37	9.9	0.01	288.40	0.96	1.00	0.52	68.02	106.94	74.86	26.41	0.93
	28	13.8	60	233.3	1.2	790	0.86	56.09	47.41	15.78	8.7	0.01	288.24	0.95	1.02	0.52	71.34	103.62	72.54	29.98	1.06
	29	14.8	56	233.3	2.0	789.8	0.86	56.09	27.98	16.84	8.6	0.01	288.22	0.95	1.08	0.52	72.60	102.37	71.66	31.83	1.12
	30	16.2	52	233.3	2.2	788.4	0.86	56.09	25.41	18.42	9.2	0.01	288.31	0.94	1.17	0.52	72.47	102.50	71.75	34.78	1.22
	31	17.5	49	233.3	2.5	787.2	0.86	56.09	22.56	20.00	8.8	0.01	288.26	0.94	1.28	0.52	74.82	100.14	70.10	40.54	1.43
feb								56.09				ERR	ERR	ERR	0.00	0.00	21.34	-21.34	14.94	ERR	
	1	17.7	46	237.5	2.2	786.6	0.75	56.09	26.07	20.25	8.8	0.01	288.26	0.94	1.27	0.52	67.60	110.50	77.35	42.25	1.49
	2	18.1	54	237.5	1.2	786	0.75	56.09	46.73	20.77	10.4	0.01	288.48	0.94	1.30	0.52	64.28	113.81	79.67	41.18	1.45
	3	17.2	57	237.5	1.1	785.8	0.75	56.09	52.76	19.62	10.9	0.01	288.55	0.94	1.24	0.52	62.41	115.68	80.98	37.33	1.31
	4	16.5	58	237.5	1.8	785.7	0.75	56.09	31.15	18.77	10.7	0.01	288.52	0.94	1.19	0.52	62.23	115.86	81.10	32.97	1.16
	5	16.5	61	237.5	1.7	785.9	0.75	56.09	32.71	18.77	11.4	0.01	288.62	0.94	1.19	0.52	60.76	117.33	82.13	31.25	1.10
	6	12.8	70	237.5	2.0	786.5	0.75	56.09	27.72	14.78	10.4	0.01	288.48	0.96	0.97	0.52	59.73	118.36	82.85	20.66	0.73
	7	8.7	72	237.5	2.2	788.1	0.75	56.09	25.46	11.25	8.1	0.01	288.16	0.97	0.76	0.52	61.12	116.97	81.88	15.38	0.54
	8	12.8	58	237.5	1.4	787.3	0.75	56.09	38.71	14.78	8.2	0.01	288.17	0.95	0.97	0.52	64.52	113.57	79.50	28.39	1.00
	9	13.6	57	237.5	2.2	787.2	0.75	56.09	25.76	15.58	8.6	0.01	288.23	0.95	1.01	0.52	64.32	113.77	79.64	28.30	1.00
	10	14.5	62	237.5	2.1	786.5	0.75	56.09	26.70	16.51	9.7	0.01	288.38	0.95	1.07	0.52	62.66	115.43	80.80	28.18	0.99
	11	14.2	67	237.5	2.3	786.7	0.75	56.09	24.78	16.19	10.2	0.01	288.45	0.95	1.05	0.52	61.33	116.76	81.73	25.41	0.89
	12	13.4	81	237.5	2.1	788.1	0.75	56.09	26.43	15.37	12.3	0.01	288.74	0.95	1.00	0.52	56.46	121.64	85.14	16.74	0.59
	13	16.4	61	237.5	2.3	787.7	0.75	56.09	23.92	18.65	10.5	0.01	288.49	0.94	1.19	0.52	62.58	115.51	80.86	32.23	1.13
	14	16.4	49	237.5	2.0	787.3	0.75	56.09	27.84	18.65	8.7	0.01	288.24	0.94	1.19	0.52	66.63	111.46	78.02	37.84	1.33
	15	17.1	49	237.5	1.3	786.9	0.75	56.09	42.21	19.50	8.8	0.01	288.26	0.94	1.23	0.52	67.04	111.05	77.74	41.19	1.45
	16	17.2	38	237.5	1.9	786.4	0.75	56.09	29.47	19.62	7.3	0.01	288.05	0.94	1.24	0.52	70.86	107.23	75.06	44.76	1.58
	17	16.5	45	237.5	2.1	786.3	0.75	56.09	26.70	18.77	7.9	0.01	288.13	0.94	1.19	0.52	68.66	109.43	76.60	40.39	1.42
	18	17.4	42	237.5	2.2	786.8	0.75	56.09	25.07	19.87	7.7	0.01	288.10	0.94	1.25	0.52	70.03	108.06	75.65	44.17	1.56
	19	17.2	37	237.5	2.6	787.6	0.75	56.09	21.92	19.62	6.6	0.01	287.95	0.94	1.24	0.52	72.74	105.35	73.75	46.45	1.64
	20	18	24	237.5	2.7	787.2	0.75	56.09	20.67	20.64	4.4	0.00	287.65	0.94	1.30	0.52	80.26	97.83	68.48	55.87	1.97
	21	18.8	26	237.5	2.5	786.5	0.75	56.09	22.68	21.70	4.8	0.00	287.70	0.94	1.36	0.52	79.80	98.29	68.80	57.73	2.03
	22	18.2	31	237.5	2.2	787.1	0.75	56.09	25.66	20.90	6.2	0.00	287.90	0.94	1.31	0.52	74.87	103.22	72.25	51.43	1.81
	23	17.8	42	237.5	1.8	787.6	0.75	56.09	30.79	20.38	8.4	0.01	288.20	0.94	1.28	0.52	68.66	109.43	76.60	44.04	1.55
	24	16.8	55	237.5	2.7	788	0.75	56.09	20.77	19.13	9.9	0.01	288.41	0.94	1.21	0.52	64.24	113.85	79.70	35.12	1.24
	25	13.9	51	237.5	1.7	789.2	0.75	56.09	33.81	15.88	7.8	0.01	288.11	0.95	1.03	0.52	66.47	111.62	78.13	32.42	1.14
	26	14.4	34	237.5	1.8	788.6	0.75	56.09	30.57	16.41	5.3	0.00	287.77	0.95	1.06	0.52	73.59	104.50	73.15	40.81	1.44
	27	14.1	29	237.5	1.2	788	0.75	56.09	46.40	16.09	4	0.00	287.59	0.95	1.04	0.52	77.37	100.72	70.51	43.77	1.54
	28	14.4	29	237.5	2.2	787.7	0.75	56.09	26.01	16.41	4.1	0.00	287.61	0.95	1.06	0.52	77.36	100.74	70.52	44.11	1.55

mar								56.09												ERR	
	1	14.6	26	256.0	1.5	788.4	0.72	56.09	37.71	16.62	3.7	0.00	287.55	0.95	1.07	0.52	76.58	115.40	80.78	80.11	2.82
	2	14.1	25	256.0	1.8	788.9	0.72	56.09	30.64	16.09	3.6	0.00	287.54	0.95	1.04	0.52	76.39	115.58	80.91	79.59	2.80
	3	14	25	256.0	1.5	789.1	0.72	56.09	37.60	15.99	3.6	0.00	287.54	0.96	1.04	0.52	76.29	115.69	80.98	77.67	2.73
	4	14.7	28	256.0	1.8	787.9	0.72	56.09	30.93	16.73	4.5	0.00	287.66	0.95	1.08	0.52	74.07	117.90	82.53	78.30	2.76
	5	17.1	33	256.0	2.3	785.5	0.72	56.09	24.69	19.50	5.7	0.00	287.83	0.94	1.23	0.52	72.94	119.04	83.33	87.57	3.08
	6	18.2	36	256.0	2.5	785	0.72	56.09	22.25	20.90	7.2	0.01	288.04	0.93	1.31	0.52	69.95	122.03	85.42	87.71	3.09
	7	19.1	43	256.0	1.7	785.8	0.72	56.09	33.55	22.11	9	0.01	288.29	0.93	1.38	0.52	66.37	125.61	87.93	82.46	2.90
	8	19.5	46	256.0	1.6	787	0.72	56.09	34.71	22.67	10.2	0.01	288.45	0.93	1.41	0.52	64.00	127.98	89.59	79.59	2.80
	9	19.9	50	256.0	2.0	787.6	0.72	56.09	27.55	23.24	10.7	0.01	288.52	0.93	1.44	0.52	63.25	128.73	90.11	81.02	2.85
	10	19.9	47	256.0	2.1	787.9	0.72	56.09	26.80	23.24	10.5	0.01	288.49	0.93	1.44	0.52	63.69	128.29	89.80	82.11	2.89
	11	20.1	43	256.0	2.3	788.1	0.72	56.09	24.01	23.53	9.8	0.01	288.39	0.93	1.45	0.52	65.42	126.55	88.59	87.40	3.08
	12	20	51	256.0	1.8	787.9	0.72	56.09	30.50	23.38	11.3	0.01	288.60	0.93	1.44	0.52	62.05	129.93	90.95	78.58	2.77
	13	18.9	49	256.0	1.5	788.2	0.72	56.09	36.45	21.84	10.3	0.01	288.46	0.94	1.36	0.52	63.28	128.72	90.10	75.21	2.65
	14	19	40	256.0	1.6	788	0.72	56.09	35.17	21.97	8.3	0.01	288.19	0.94	1.37	0.52	67.95	124.03	86.82	84.57	2.98
	15	19	47	256.0	1.4	787.5	0.72	56.09	39.89	21.97	9.7	0.01	288.38	0.93	1.37	0.52	64.67	127.30	89.11	77.96	2.74
	16	19	52	256.0	2.6	786.1	0.72	56.09	21.74	21.97	11.1	0.01	288.58	0.93	1.37	0.52	61.63	130.35	91.24	73.41	2.58
	17	18.3	52	256.0	1.6	785	0.72	56.09	34.62	21.03	10.7	0.01	288.52	0.93	1.32	0.52	61.88	130.10	91.07	69.90	2.46
	18	19.8	52	256.0	3.0	785.4	0.72	56.09	18.69	23.08	11.5	0.01	288.63	0.93	1.43	0.52	61.46	130.52	91.36	77.56	2.73
	19	20.1	49	256.0	2.2	786.8	0.72	56.09	25.81	23.53	10.7	0.01	288.52	0.93	1.45	0.52	63.42	128.55	89.99	82.70	2.91
	20	19.3	43	256.0	2.0	787.6	0.72	56.09	28.63	22.39	8.3	0.01	288.19	0.93	1.39	0.52	68.23	123.75	86.63	87.93	3.10
	21	18.8	48	256.0	2.0	787.8	0.72	56.09	27.72	21.70	9.3	0.01	288.32	0.94	1.35	0.52	65.40	126.57	88.60	80.17	2.82
	22	20.1	41	256.0	2.1	787.9	0.72	56.09	26.81	23.53	9	0.01	288.28	0.93	1.45	0.52	67.28	124.70	87.29	90.49	3.19
	23	19.2	40	256.0	1.8	789	0.72	56.09	31.91	22.25	8.5	0.01	288.21	0.94	1.38	0.52	67.65	124.33	87.03	85.62	3.01
	24	19.6	40	256.0	2.6	788.7	0.72	56.09	21.21	22.81	8.7	0.01	288.24	0.93	1.41	0.52	67.54	124.44	87.11	90.04	3.17
	25	19.6	45	256.0	2.3	787.9	0.72	56.09	24.23	22.81	9.7	0.01	288.38	0.93	1.41	0.52	65.20	126.77	88.74	84.31	2.97
	26	19.6	43	256.0	2.0	787.2	0.72	56.09	28.69	22.81	9.3	0.01	288.32	0.93	1.41	0.52	66.12	125.85	88.10	85.27	3.00
	27	18.4	56	256.0	2.3	787.1	0.72	56.09	24.23	21.16	11.4	0.01	288.61	0.93	1.32	0.52	60.50	131.48	92.03	67.56	2.38
	28	16	72	256.0	2.2	787.7	0.72	56.09	25.66	18.18	12.7	0.01	288.79	0.94	1.16	0.52	56.01	135.96	95.17	45.08	1.59
	29	16.2	69	256.0	2.2	788.2	0.72	56.09	25.16	18.42	12.1	0.01	288.71	0.94	1.17	0.52	57.32	134.66	94.26	49.36	1.74
	30	16.9	70	256.0	3.1	788	0.72	56.09	17.92	19.25	12.5	0.01	288.76	0.94	1.22	0.52	57.10	134.88	94.41	50.83	1.79
	31	17.1	65	256.0	2.3	787.3	0.72	56.09	24.23	19.50	11.9	0.01	288.68	0.94	1.23	0.52	58.43	133.55	93.48	58.20	1.98
apr								56.09				ERR	ERR	ERR	0.00	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	19	53	260.4	2.7	786.7	0.67	56.09	20.77	21.97	11.2	0.01	288.59	0.93	1.37	0.52	58.25	137.05	95.94	73.71	2.59
	2	17.1	67	260.4	2.3	786.7	0.67	56.09	24.23	19.50	12.6	0.01	288.78	0.94	1.23	0.52	54.12	141.18	98.83	53.36	1.88
	3	16.2	73	260.4	2.1	787	0.67	56.09	27.09	18.42	12.7	0.01	288.79	0.94	1.17	0.52	53.27	142.03	99.42	47.41	1.67
	4	17.1	67	260.4	1.6	786.9	0.67	56.09	34.43	19.50	12.3	0.01	288.74	0.94	1.23	0.52	54.67	140.63	98.44	56.22	1.98
	5	15.9	77	260.4	2.8	788.2	0.67	56.09	20.13	18.07	13.5	0.01	288.90	0.94	1.15	0.52	51.64	143.66	100.56	39.50	1.39
	6	15.1	82	260.4	2.6	788.3	0.67	56.09	21.45	17.16	13.5	0.01	288.90	0.95	1.10	0.52	51.08	144.23	100.96	34.56	1.22
	7	17.9	70	260.4	2.0	786.7	0.67	56.09	28.76	20.51	13.5	0.01	288.91	0.94	1.29	0.52	53.08	142.22	99.55	55.03	1.94
	8	18	69	260.4	2.4	786.5	0.67	56.09	23.04	20.84	13.8	0.01	288.95	0.93	1.30	0.52	52.63	142.68	99.87	53.27	1.87
	9	18.1	66	260.4	1.3	787.2	0.67	56.09	43.62	20.77	13.2	0.01	288.86	0.94	1.30	0.52	53.77	141.53	99.07	59.46	2.09
	10	18.3	68	260.4	2.0	787.9	0.67	56.09	27.84	21.03	13.7	0.01	288.93	0.94	1.32	0.52	53.02	142.28	99.60	56.65	1.99
	11	17.5	69	260.4	2.1	787.7	0.67	56.09	26.43	20.00	13.1	0.01	288.85	0.94	1.26	0.52	53.51	141.79	99.25	53.90	1.90
	12	16.9	71	260.4	2.3	787.1	0.67	56.09	24.83	19.25	13.1	0.01	288.85	0.94	1.22	0.52	53.07	142.23	99.56	49.56	1.74
	13	15.6	82	260.4	2.1	788.1	0.67	56.09	27.26	17.72	14	0.01	288.97	0.94	1.13	0.52	50.56	144.73	101.31	37.00	1.30
	14	14.5	83	260.4	2.7	789.7	0.67	56.09	20.54	16.51	13.7	0.01	288.93	0.95	1.07	0.52	50.31	144.99	101.49	29.22	1.03
	15	12.3	93	260.4	2.7	790.2	0.67	56.09	20.90	14.31	13.3	0.01	288.87	0.96	0.94	0.52	49.45	145.85	102.10	17.91	0.63
	16	14.1	81	260.4	2.2	789.5	0.67	56.09	25.16	16.09	12.8	0.01	288.80	0.95	1.04	0.52	51.57	143.73	100.61	33.12	1.17
	17	13	81	260.4	2.8	788.3	0.67	56.09	20.13	14.98	12	0.01	288.69	0.95	0.98	0.52	52.18	143.13	100.19	29.21	1.03
	18	14.6	72	260.4	1.7	787.8	0.67	56.09	32.47	16.82	11.6	0.01	288.64	0.95	1.07	0.52	54.08	141.22	98.86	44.05	1.55
	19	13.9	74	260.4	2.6	788.9	0.67	56.09	21.70	15.88	11.4	0.01	288.61	0.95	1.03	0.52	53.92	141.38	98.97	38.50	1.36
	20	16.2	67	260.4	1.5	787.6	0.67	56.09	37.71	18.42	11.8	0.01	288.67	0.94	1.17	0.52	54.92	140.39	98.27	53.39	1.88
	21	18.8	62	260.4	1.6	787	0.67	56.09	34.43	21.70	12.9	0.01	288.82	0.93	1.35	0.52	54.84	140.46	98.32	64.39	2.27
	22	19.1	61	260.4	2.9	786.3	0.67	56.09	19.10	22.11	12.6	0.01	288.78	0.93	1.38	0.52	55.63	139.68	97.77	67.12	2.36
	23	20.3	60	260.4	2.0	786.1	0.67	56.09	28.57	23.82	13.3	0.01	288.88	0.93	1.47	0.52	55.23	140.07	98.05	72.68	2.56
	24	19.9	57	260.4	3.1	785.9	0.67	56.09	18.00	23.24	12.5	0.01	288.77	0.93	1.44	0.52	56.43	138.87	97.21	73.79	2.60
	25	18.8	63	260.4	1.9	785.4	0.67	56.09	30.01	21.70	13.1	0.01	288.85	0.93	1.35	0.52	54.47	140.83	98.58	63.18	2.22
	26	19.6	55	260.4	1.4	785.3	0.67	56.09	41.28	22.81	11.7	0.01	288.66	0.93	1.41	0.52	57.74	137.56	96.29	74.63	2.63
	27	18.8	60	260.4	1.8	785.7	0.67	56.09	31.68	21.70	12.5	0.01	288.77	0.93	1.35	0.52	55.58	139.72	97.80	66.05	2.32
	28	18.6	61	260.4	1.7	785.8	0.67	56.09	33.38	21.43	12.6	0.01	288.78	0.93	1.34	0.52	55.25	140.06	98.04	64.36	2.27
	29	17.7	67	260.4	1.0	785.6	0.67	56.09	53.63	20.25	12.9	0.01	288.83	0.93	1.27	0.52	54.02	141.28	98.90	59.24	2.09
	30	18.3	62	260.4	1.7	785.5	0.67	56.09	32.96	21.03	12	0.01	288.70	0.93	1.32	0.52	56.15	139.16	97.41	65.10	2.29

may							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	20.3	53	276.7	1.4	786.1	0.72	56.09	40.51	23.82	11.7	0.01	288.66	0.93	1.47	0.52	61.46	146.08	102.26	80.78	2.84
2	20.1	49	276.7	2.6	786.9	0.72	56.09	21.81	23.53	10.7	0.01	288.52	0.93	1.45	0.52	63.42	144.12	100.88	85.37	3.01
3	18.2	62	276.7	3.0	787.8	0.72	56.09	18.56	20.90	12.8	0.01	288.81	0.94	1.31	0.52	57.54	150.00	105.00	60.21	2.12
4	19	59	276.7	2.9	786.6	0.72	56.09	19.19	21.97	12	0.01	288.70	0.93	1.37	0.52	58.77	147.77	103.44	70.53	2.48
5	20.2	55	276.7	1.8	785.5	0.72	56.09	30.64	23.67	11.8	0.01	288.67	0.93	1.46	0.52	61.17	146.37	102.46	80.17	2.82
6	19.6	58	276.7	2.9	785.4	0.72	56.09	19.16	22.81	12	0.01	288.70	0.93	1.41	0.52	60.26	147.28	103.10	75.09	2.64
7	19.7	61	276.7	2.3	785.5	0.72	56.09	23.96	22.95	13.2	0.01	288.87	0.93	1.42	0.52	57.95	149.59	104.71	69.94	2.46
8	21.4	42	276.7	1.7	785.8	0.72	56.09	33.13	25.49	10	0.01	288.42	0.92	1.56	0.52	66.13	141.41	98.99	95.86	3.37
9	20.1	44	276.7	1.2	787.2	0.72	56.09	46.40	23.53	9.8	0.01	288.39	0.93	1.45	0.52	65.42	142.12	99.48	86.33	3.04
10	21.1	43	276.7	1.6	785.9	0.72	56.09	35.95	25.02	10.4	0.01	288.48	0.93	1.53	0.52	64.96	142.58	99.81	91.66	3.23
11	21.8	41	276.7	3.3	785.2	0.72	56.09	17.13	26.12	10.4	0.01	288.48	0.92	1.59	0.52	65.58	141.96	99.38	101.25	3.56
12	19.6	64	276.7	3.6	785.2	0.72	56.09	15.78	22.81	14.2	0.01	289.01	0.93	1.41	0.52	55.96	151.58	106.11	62.99	2.22
13	17.6	80	276.7	3.3	787.1	0.72	56.09	16.84	20.13	15	0.01	289.11	0.94	1.27	0.52	53.01	154.53	108.17	43.23	1.52
14	17.3	75	276.7	3.2	788.6	0.72	56.09	17.29	19.75	13.9	0.01	288.96	0.94	1.25	0.52	54.77	152.77	106.94	47.23	1.66
15	17.8	64	276.7	1.6	789.4	0.72	56.09	35.85	20.38	13.2	0.01	288.86	0.94	1.28	0.52	56.46	151.06	105.76	58.21	2.05
16	16.8	76	276.7	2.7	788.6	0.72	56.09	20.77	19.13	14.4	0.01	289.03	0.94	1.21	0.52	53.49	154.05	107.83	42.02	1.48
17	18.3	67	276.7	2.4	786.6	0.72	56.09	23.79	21.03	13.7	0.01	288.93	0.93	1.32	0.52	55.91	151.64	106.15	57.19	2.01
18	19.4	56	276.7	1.1	786.6	0.72	56.09	49.56	22.53	11.7	0.01	288.66	0.93	1.40	0.52	60.71	146.83	102.78	75.10	2.64
19	20.2	49	276.7	1.7	787	0.72	56.09	32.63	23.67	10.2	0.01	288.45	0.93	1.46	0.52	64.61	142.93	100.05	87.03	3.06
20	20.3	43	276.7	1.6	787	0.72	56.09	34.99	23.82	9.1	0.01	288.30	0.93	1.47	0.52	67.23	140.32	98.22	92.00	3.24
21	20.6	38	276.7	1.3	786.9	0.72	56.09	43.04	24.27	8.5	0.01	288.21	0.93	1.49	0.52	68.95	138.59	97.01	94.64	3.33
22	21.1	35	276.7	1.3	786.8	0.72	56.09	43.91	25.02	8.4	0.01	288.20	0.93	1.53	0.52	69.67	137.87	96.51	97.77	3.44
23	21.3	36	276.7	1.8	787.2	0.72	56.09	31.61	25.33	9.1	0.01	288.30	0.93	1.55	0.52	68.15	139.39	97.58	99.37	3.50
24	20.8	35	276.7	1.1	786.8	0.72	56.09	49.56	24.57	8.2	0.01	288.17	0.93	1.51	0.52	69.89	137.66	96.36	95.52	3.36
25	20.1	33	276.7	1.2	786.4	0.72	56.09	45.12	23.53	7.4	0.01	288.06	0.93	1.45	0.52	71.26	136.28	95.40	95.38	3.36
26	21.2	33	276.7	1.5	786.5	0.72	56.09	37.60	25.18	7.8	0.01	288.12	0.93	1.54	0.52	71.29	136.25	95.38	102.33	3.60
27	21.9	32	276.7	1.7	787.3	0.72	56.09	33.72	26.26	8.2	0.01	288.17	0.93	1.60	0.52	70.94	136.61	95.62	106.49	3.75
28	22.6	29	276.7	1.6	787.1	0.72	56.09	34.89	27.42	7.6	0.01	288.09	0.92	1.66	0.52	73.18	134.36	94.05	113.05	3.98
29	21.4	34	276.7	2.6	786.6	0.72	56.09	21.59	25.49	8.3	0.01	288.19	0.93	1.56	0.52	70.20	137.34	96.14	107.08	3.77
30	21.7	35	276.7	1.2	785.7	0.72	56.09	48.46	25.96	8.7	0.01	288.24	0.92	1.58	0.52	69.49	138.05	96.63	99.15	3.49
31	22.6	47	276.7	2.0	785.5	0.72	56.09	27.96	27.42	12.1	0.01	288.71	0.92	1.66	0.52	62.56	144.98	101.49	96.53	3.40
jun							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	22.7	43	257.0	1.7	786.5	0.64	56.09	33.72	27.59	11.5	0.01	288.63	0.92	1.67	0.52	58.66	134.06	93.84	96.71	3.40
2	23.3	39	257.0	1.4	786	0.64	56.09	39.65	28.61	10.2	0.01	288.45	0.92	1.72	0.52	61.83	130.89	91.63	104.04	3.66
3	23.1	32	257.0	1.8	784.8	0.64	56.09	31.53	28.26	8.8	0.01	288.26	0.92	1.71	0.52	64.75	127.97	89.58	111.40	3.92
4	22.9	36	257.0	2.1	784.7	0.64	56.09	26.98	27.92	9.7	0.01	288.38	0.92	1.69	0.52	62.57	130.15	91.11	108.15	3.81
5	21.8	53	257.0	2.5	785.7	0.64	56.09	22.07	26.12	13.2	0.01	288.87	0.92	1.59	0.52	54.71	138.01	96.61	84.78	2.98
6	21.8	47	257.0	1.8	785.8	0.64	56.09	30.43	26.12	11.3	0.01	288.60	0.92	1.59	0.52	58.34	134.38	94.06	92.02	3.24
7	22	37	257.0	1.5	784.8	0.64	56.09	38.04	26.44	9.3	0.01	288.33	0.92	1.61	0.52	62.68	130.04	91.03	99.60	3.51
8	22.3	33	257.0	1.6	784.2	0.64	56.09	35.27	26.93	8.1	0.01	288.16	0.92	1.63	0.52	65.68	127.05	88.93	107.24	3.77
9	22.1	29	257.0	2.2	785	0.64	56.09	25.51	26.60	7.3	0.01	288.05	0.92	1.62	0.52	67.43	125.29	87.70	113.86	4.01
10	22.2	42	257.0	1.7	785.3	0.64	56.09	33.72	26.76	10.9	0.01	288.55	0.92	1.63	0.52	59.47	133.25	93.28	95.72	3.37
11	22.6	36	257.0	2.1	784.5	0.64	56.09	27.20	27.42	9.6	0.01	288.37	0.92	1.66	0.52	62.53	130.19	91.13	106.29	3.74
12	22.3	28	257.0	1.9	784.4	0.64	56.09	29.60	26.93	7.1	0.01	288.02	0.92	1.63	0.52	68.12	124.60	87.22	113.98	4.01
13	22.2	26	257.0	1.7	785.2	0.64	56.09	32.39	26.76	6.5	0.01	287.94	0.92	1.63	0.52	69.57	123.15	86.20	114.40	4.03
14	22.4	33	257.0	1.7	785.9	0.64	56.09	32.47	27.09	8.7	0.01	288.24	0.92	1.64	0.52	64.37	128.35	89.85	106.61	3.75
15	23.4	41	257.0	2.1	785.3	0.64	56.09	27.26	28.78	10.8	0.01	288.54	0.92	1.73	0.52	60.65	132.07	92.45	106.92	3.76
16	23.6	37	257.0	2.8	785.3	0.64	56.09	19.98	29.13	10.1	0.01	288.44	0.92	1.75	0.52	62.29	130.43	91.30	115.26	4.06
17	24.4	39	257.0	2.3	785.4	0.64	56.09	24.83	30.56	11	0.01	288.56	0.91	1.83	0.52	61.05	131.67	92.17	114.93	4.05
18	23.6	29	257.0	2.0	785.8	0.64	56.09	27.84	29.13	8	0.01	288.15	0.92	1.75	0.52	67.08	125.64	87.95	120.29	4.23
19	23.3	36	257.0	2.4	785.7	0.64	56.09	23.62	28.61	9.5	0.01	288.35	0.92	1.72	0.52	63.35	129.37	90.56	113.72	4.00
20	23.5	31	257.0	2.3	785.3	0.64	56.09	24.23	28.96	9	0.01	288.29	0.92	1.74	0.52	64.64	128.08	89.65	117.23	4.13
21	22.7	32	257.0	2.2	786.2	0.64	56.09	25.86	27.59	8.7	0.01	288.24	0.92	1.67	0.52	64.63	128.09	89.66	111.79	3.93
22	21.8	34	257.0	1.4	786.8	0.64	56.09	39.77	26.12	8.9	0.01	288.27	0.92	1.59	0.52	63.40	129.32	90.53	99.37	3.50
23	21.1	31	257.0	1.5	786	0.64	56.09	36.55	25.02	7.8	0.01	288.12	0.93	1.53	0.52	65.32	127.40	89.18	100.35	3.53
24	21.5	40	257.0	2.1	785	0.64	56.09	26.98	25.64	10.2	0.01	288.45	0.92	1.57	0.52	60.34	132.38	92.67	95.66	3.37
25	22	51	257.0	2.0	784.4	0.64	56.09	27.66	26.44	12.5	0.01	288.77	0.92	1.61	0.52	56.17	136.55	95.59	88.72	3.12
26	22.2	43	257.0	3.1	784.5	0.64	56.09	18.17	26.76	10.8	0.01	288.54	0.92	1.63	0.52	59.67	133.05	93.13	101.02	3.56
27	23.5	34	257.0	2.8	785.2	0.64	56.09	20.07	28.96	8.9	0.01	288.27	0.92	1.74	0.52	64.87	127.85	89.49	120.23	4.23
28	23.2	41	257.0	2.5	785.5	0.64	56.09	22.18	28.44	10.7	0.01	288.52	0.92	1.71	0.52	60.69	132.03	92.42	108.00	3.80
29	24.2	39	257.0	1.8	784.7	0.64	56.09	31.68	30.20	10.5	0.01	288.49	0.91	1.81	0.52	61.94	130.78	91.55	112.18	3.95
30	24.1	30	257.0	1.7	784.3	0.64	56.09	33.04	30.02	8.1	0.01	288.16	0.92	1.80	0.52	67.29	125.43	87.80	120.34	4.24

jul																				
							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	23.7	25	241.2	1.8	783.7	0.57	56.09	31.91	29.31	7.1	0.01	288.02	0.92	1.76	0.52	63.96	116.93	81.85	121.02	4.26
2	23.2	29	241.2	1.6	783.7	0.57	56.09	35.75	28.44	7.3	0.01	288.05	0.92	1.71	0.52	63.06	117.83	82.48	114.89	4.04
3	22.8	23	241.2	1.4	783.7	0.57	56.09	41.28	27.76	6.1	0.00	287.89	0.92	1.68	0.52	65.62	115.27	80.69	113.84	4.01
4	22.8	30	241.2	3.1	784.3	0.57	56.09	18.30	27.76	7.8	0.01	288.12	0.92	1.68	0.52	61.58	119.30	83.51	120.32	4.24
5	23.1	36	241.2	3.0	784.2	0.57	56.09	18.96	28.26	9.6	0.01	288.37	0.92	1.71	0.52	58.01	122.88	86.02	113.27	3.99
6	22.2	42	241.2	2.4	784	0.57	56.09	22.96	26.76	10.8	0.01	288.54	0.92	1.63	0.52	54.98	125.91	88.14	98.31	3.46
7	23.4	40	241.2	3.3	784.3	0.57	56.09	17.22	28.78	10.4	0.01	288.48	0.92	1.73	0.52	56.65	124.24	86.97	112.77	3.97
8	23.7	42	241.2	2.7	784.6	0.57	56.09	20.77	29.31	10.7	0.01	288.52	0.92	1.76	0.52	56.29	124.59	87.21	111.76	3.93
9	23.9	36	241.2	2.1	784	0.57	56.09	26.70	29.66	9.6	0.01	288.37	0.91	1.78	0.52	58.63	122.25	85.58	115.06	4.05
10	24.5	34	241.2	2.5	783.1	0.57	56.09	22.56	30.75	9.5	0.01	288.36	0.91	1.83	0.52	59.32	121.57	85.10	122.83	4.32
11	22.5	40	241.2	2.3	783.1	0.57	56.09	24.23	27.26	10.2	0.01	288.46	0.92	1.65	0.52	56.35	124.53	87.17	102.95	3.62
12	22.6	43	241.2	2.5	784.2	0.57	56.09	22.18	27.42	11.2	0.01	288.59	0.92	1.66	0.52	54.53	126.36	88.45	99.80	3.51
13	22.9	50	241.2	2.9	784.5	0.57	56.09	19.24	27.92	12.9	0.01	288.63	0.92	1.69	0.52	51.68	129.20	90.44	94.91	3.34
14	23.2	47	241.2	2.4	783.7	0.57	56.09	23.49	28.44	12.8	0.01	288.82	0.92	1.71	0.52	52.07	128.82	90.17	96.49	3.40
15	22.8	46	241.2	2.6	783.6	0.57	56.09	21.81	27.76	12.2	0.01	288.73	0.92	1.68	0.52	52.85	128.04	89.63	96.69	3.40
16	21.3	45	241.2	2.2	783.9	0.57	56.09	25.86	25.33	11.3	0.01	288.61	0.92	1.55	0.52	53.39	127.50	89.25	88.30	3.11
17	22.6	38	241.2	2.7	783.7	0.57	56.09	20.74	27.42	9.9	0.01	288.41	0.92	1.66	0.52	57.02	123.87	86.71	106.77	3.76
18	22.8	40	241.2	2.8	783.7	0.57	56.09	20.26	27.76	10.8	0.01	288.54	0.92	1.68	0.52	55.43	125.46	87.82	104.16	3.67
19	23.4	39	241.2	1.6	783.9	0.57	56.09	34.07	28.78	10.7	0.01	288.52	0.92	1.73	0.52	56.07	124.82	87.37	103.33	3.64
20	24.5	38	241.2	1.5	784	0.57	56.09	37.60	30.75	10.9	0.01	288.55	0.91	1.83	0.52	56.52	124.37	87.08	108.66	3.82
21	23	47	241.2	3.3	785	0.57	56.09	17.08	28.09	12.5	0.01	288.77	0.92	1.70	0.52	52.46	128.43	89.90	98.56	3.47
22	23.3	44	241.2	2.8	785.7	0.57	56.09	20.29	28.61	11.7	0.01	288.66	0.92	1.72	0.52	54.11	126.77	88.74	103.82	3.65
23	23.7	35	241.2	3.6	784.5	0.57	56.09	15.76	29.31	9.6	0.01	288.37	0.92	1.76	0.52	58.48	122.41	85.69	120.47	4.24
24	22.4	43	241.2	2.8	783.3	0.57	56.09	19.80	27.09	10.8	0.01	288.54	0.92	1.64	0.52	55.13	125.76	88.03	101.12	3.56
25	21.3	50	241.2	2.4	783.9	0.57	56.09	23.16	25.33	11.5	0.01	288.63	0.92	1.55	0.52	53.03	127.86	89.50	87.98	3.10
26	22.8	41	241.2	3.1	784.1	0.57	56.09	18.22	27.76	10.5	0.01	288.50	0.92	1.68	0.52	56.00	124.89	87.42	106.64	3.75
27	23.4	39	241.2	3.0	784.4	0.57	56.09	18.88	28.78	10.8	0.01	288.54	0.92	1.73	0.52	55.88	125.01	87.51	109.80	3.86
28	23.3	41	241.2	1.7	784.6	0.57	56.09	32.55	28.61	10.7	0.01	288.52	0.92	1.72	0.52	55.99	124.89	87.43	103.23	3.63
29	22.6	50	241.2	2.9	785.6	0.57	56.09	19.65	27.42	12.8	0.01	288.81	0.92	1.66	0.52	51.65	129.24	90.47	92.78	3.27
30	21.9	51	241.2	2.9	785.2	0.57	56.09	19.38	26.28	12.4	0.01	288.76	0.92	1.60	0.52	51.86	129.03	90.32	89.13	3.14
31	22.5	43	241.2	2.0	784.2	0.57	56.09	27.84	27.28	10.7	0.01	288.52	0.92	1.65	0.52	55.39	125.50	87.85	99.25	3.49
aug							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	23.6	36	240.4	1.6	783.6	0.58	56.09	35.75	29.13	9.4	0.01	288.34	0.92	1.75	0.52	59.52	120.78	84.53	108.87	3.83
2	24.4	27	240.4	1.9	784.4	0.58	56.09	29.08	30.56	7.2	0.01	288.04	0.91	1.83	0.52	65.11	115.17	80.62	127.19	4.48
3	25.2	23	240.4	2.8	783.9	0.58	56.09	20.07	32.06	7	0.01	288.01	0.91	1.90	0.52	66.30	113.98	79.79	142.23	5.01
4	22.3	45	240.4	2.6	784.7	0.58	56.09	21.95	26.93	11.7	0.01	288.66	0.92	1.63	0.52	54.04	126.24	88.37	94.91	3.34
5	22.8	45	240.4	2.8	784.2	0.58	56.09	20.38	27.76	11.7	0.01	288.66	0.92	1.68	0.52	54.41	125.87	88.11	99.49	3.50
6	23.9	32	240.4	1.9	783.9	0.58	56.09	28.88	29.66	8.4	0.01	288.20	0.92	1.78	0.52	61.91	118.37	82.86	118.70	4.18
7	24.2	25	240.4	2.6	783.9	0.58	56.09	21.28	30.20	7.4	0.01	288.07	0.91	1.81	0.52	64.46	115.82	81.06	131.03	4.61
8	20.9	57	240.4	2.0	785.4	0.58	56.09	28.76	24.72	13.5	0.01	288.91	0.92	1.52	0.52	49.90	130.38	91.27	74.57	2.63
9	19.2	69	240.4	3.0	786.4	0.58	56.09	18.96	22.25	14.7	0.01	289.07	0.93	1.38	0.52	46.83	133.45	93.41	55.66	1.96
10	21.2	64	240.4	3.6	786.3	0.58	56.09	15.73	25.18	14.8	0.01	289.09	0.92	1.54	0.52	47.97	132.31	92.62	71.07	2.50
11	23.3	55	240.4	2.0	785.5	0.58	56.09	28.45	28.61	14	0.01	288.98	0.92	1.72	0.52	50.69	129.59	90.71	90.26	3.18
12	22.5	50	240.4	2.7	784.7	0.58	56.09	20.70	27.26	12.5	0.01	288.77	0.92	1.65	0.52	52.74	127.54	89.28	92.98	3.27
13	21.9	53	240.4	2.6	784.4	0.58	56.09	21.92	26.28	12.7	0.01	288.80	0.92	1.60	0.52	51.96	128.32	89.82	86.87	3.06
14	20.7	54	240.4	3.9	786	0.58	56.09	14.38	24.42	12.5	0.01	288.77	0.93	1.50	0.52	51.47	128.81	90.17	79.61	2.80
15	21.9	48	240.4	2.4	786.7	0.58	56.09	23.16	26.28	12	0.01	288.70	0.92	1.60	0.52	53.20	127.08	88.95	89.98	3.17
16	22.8	43	240.4	2.6	785.5	0.58	56.09	21.74	27.76	10.8	0.01	288.53	0.92	1.68	0.52	56.10	124.18	86.93	103.33	3.64
17	22.7	37	240.4	1.9	785.2	0.58	56.09	29.08	27.59	9.5	0.01	288.36	0.92	1.67	0.52	58.60	121.68	85.18	105.28	3.71
18	23.1	35	240.4	1.3	785.8	0.58	56.09	41.67	28.26	8.7	0.01	288.24	0.92	1.71	0.52	60.60	119.68	83.78	105.77	3.72
19	23.5	28	240.4	1.6	786.2	0.58	56.09	34.90	28.96	7.8	0.01	288.12	0.92	1.74	0.52	62.90	117.35	82.15	114.86	4.04
20	24	24	240.4	2.3	786	0.58	56.09	24.89	29.84	7.2	0.01	288.04	0.92	1.79	0.52	64.78	115.52	80.87	127.63	4.49
21	24.1	24	240.4	1.4	785.4	0.58	56.09	41.28	30.02	6.9	0.01	288.00	0.92	1.80	0.52	65.57	114.71	80.30	118.47	4.17
22	23.4	35	240.4	1.9	785.6	0.58	56.09	29.47	28.78	8.8	0.01	288.26	0.92	1.73	0.52	60.63	119.65	83.75	113.09	3.98
23	23.2	31	240.4	2.7	785.7	0.58	56.09	20.51	28.44	8.3	0.01	288.19	0.92	1.71	0.52	61.55	118.73	83.11	119.35	4.20
24	23.5	40	240.4	1.8	785.4	0.58	56.09	31.38	28.96	10.6	0.01	288.51	0.92	1.74	0.52	57.02	123.28	86.28	105.30	3.71
25	22.5	49	240.4	2.7	784.1	0.58	56.09	20.41	27.26	12.7	0.01	288.80	0.92	1.65	0.52	52.38	127.90	89.53	92.07	3.24
26	21.7	51	240.4	2.9	783.9	0.58	56.09	19.30	25.96	12	0.01	288.70	0.92	1.56	0.52	53.08	127.22	89.05	89.42	3.15
27	20.6	54	240.4	2.6	784.2	0.58	56.09	21.28	24.27	11.7	0.01	288.66	0.92	1.49	0.52	52.81	127.47	89.23	81.90	2.88
28	20.8	49	240.4	2.6	785.8	0.58	56.09	21.35	24.57	11.3	0.01	288.60	0.93	1.51	0.52	53.68	126.60	88.62	85.43	3.01
29	22.9	44	240.4	1.9	784.4	0.58	56.09	29.08	27.92	11.6	0.01	288.65	0.92	1.69	0.52	54.86	125.62	87.93	97.57	3.43
30	23.5	34	240.4	1.9	784.1	0.58	56.09	29.94	28.96	9.4	0.01	288.34	0.92	1.74	0.52	59.44	120.84	84.59	111.00	3.91
31	24.4	28	240.4	1.9	784.9	0.58	56.09	29.74	30.56	8.4	0.01	288.20	0.91	1.83	0.52	62.33	117.95	82.56	121.77	4.29

sep							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	20.7	24	250.5	0.8	785.1	0.67	56.09	67.79	24.42	7.1	0.01	288.02	0.93	1.50	0.52	68.90	118.94	83.26	90.68	3.19
2	20.7	26	250.5	1.7	784.4	0.67	56.09	32.07	24.42	6.8	0.01	287.98	0.93	1.50	0.52	69.68	118.17	82.72	102.37	3.60
3	20.7	25	250.5	1.7	783.7	0.67	56.09	33.63	24.42	6.7	0.01	287.97	0.93	1.50	0.52	69.94	117.90	82.53	102.15	3.60
4	20.7	38	250.5	2.5	784.2	0.67	56.09	22.56	24.42	10	0.01	288.43	0.92	1.50	0.52	62.13	125.71	88.00	91.05	3.20
5	20.7	39	250.5	1.7	785.3	0.67	56.09	32.31	24.42	9.3	0.01	288.33	0.93	1.50	0.52	63.66	124.18	86.93	91.55	3.22
6	20.7	22	250.5	2.0	785.9	0.67	56.09	28.20	24.42	6.6	0.01	287.95	0.93	1.50	0.52	70.20	117.64	82.35	104.95	3.69
7	20.7	26	250.5	2.0	785.8	0.67	56.09	27.84	24.42	6.1	0.00	287.88	0.93	1.50	0.52	71.55	116.29	81.40	107.37	3.78
8	20.7	26	250.5	1.9	785.1	0.67	56.09	29.14	24.42	6.6	0.01	287.95	0.93	1.50	0.52	70.20	117.64	82.35	104.52	3.68
9	20.7	27	250.5	1.8	785.6	0.67	56.09	31.15	24.42	6.9	0.01	287.99	0.93	1.50	0.52	69.42	118.43	82.90	102.33	3.60
10	20.7	30	250.5	1.7	786.3	0.67	56.09	33.29	24.42	7.1	0.01	288.02	0.93	1.50	0.52	68.90	118.94	83.26	100.62	3.54
11	20.7	25	250.5	1.4	786.8	0.67	56.09	38.82	24.42	6.2	0.00	287.90	0.93	1.50	0.52	71.28	116.56	81.59	102.11	3.59
12	20.7	29	250.5	1.6	786.3	0.67	56.09	34.52	24.42	7	0.01	288.01	0.93	1.50	0.52	69.16	118.68	83.08	100.56	3.54
13	20.7	25	250.5	1.9	786	0.67	56.09	29.74	24.42	6.4	0.01	287.93	0.93	1.50	0.52	70.73	117.11	81.97	105.13	3.70
14	20.7	23	250.5	1.5	785.9	0.67	56.09	38.37	24.42	5.6	0.00	287.81	0.93	1.50	0.52	72.96	114.88	80.42	104.63	3.68
15	20.7	23	250.5	1.8	786.2	0.67	56.09	31.68	24.42	5.4	0.00	287.79	0.93	1.50	0.52	73.54	114.30	80.01	108.53	3.82
16	20.7	23	250.5	1.6	786.3	0.67	56.09	34.70	24.42	5.5	0.00	287.80	0.93	1.50	0.52	73.25	114.59	80.22	106.66	3.76
17	20.7	24	250.5	2.1	785.8	0.67	56.09	27.26	24.42	5.7	0.00	287.83	0.93	1.50	0.52	72.67	115.17	80.62	109.48	3.86
18	20.7	30	250.5	2.4	785.1	0.67	56.09	23.03	24.42	8.5	0.01	288.22	0.93	1.50	0.52	65.49	122.35	85.65	98.23	3.46
19	20.7	43	250.5	2.7	785.2	0.67	56.09	20.77	24.42	10.3	0.01	288.47	0.93	1.50	0.52	61.49	126.35	88.45	90.06	3.17
20	20.7	36	250.5	2.2	785.7	0.67	56.09	25.76	24.42	8.4	0.01	288.20	0.93	1.50	0.52	65.72	122.12	85.48	97.69	3.44
21	20.7	34	250.5	1.7	785.9	0.67	56.09	33.29	24.42	7.9	0.01	288.13	0.93	1.50	0.52	66.91	120.93	84.65	97.24	3.42
22	20.7	31	250.5	1.9	785.7	0.67	56.09	28.88	24.42	6.9	0.01	287.99	0.93	1.50	0.52	69.42	118.43	82.90	103.30	3.64
23	20.7	29	250.5	1.6	785.8	0.67	56.09	34.34	24.42	6.5	0.01	287.94	0.93	1.50	0.52	70.47	117.37	82.16	102.71	3.52
24	20.7	33	250.5	2.1	786.3	0.67	56.09	26.38	24.42	7.5	0.01	288.06	0.93	1.50	0.52	67.89	119.95	83.96	101.64	3.58
25	20.7	33	250.5	1.9	785.9	0.67	56.09	30.22	24.42	7.6	0.01	288.09	0.93	1.50	0.52	67.65	120.19	84.14	99.65	3.51
26	20.7	31	250.5	2.4	785.9	0.67	56.09	23.83	24.42	7	0.01	288.01	0.93	1.50	0.52	69.16	118.68	83.08	105.14	3.70
27	20.7	26	250.5	2.3	785.5	0.67	56.09	24.69	24.42	5.6	0.00	287.82	0.93	1.50	0.52	72.96	114.88	80.42	111.34	3.92
28	20.7	27	250.5	1.5	785.2	0.67	56.09	37.06	24.42	5.9	0.00	287.86	0.93	1.50	0.52	72.11	115.73	81.01	104.00	3.66
29	20.7	27	250.5	1.4	785	0.67	56.09	40.38	24.42	6.2	0.00	287.90	0.93	1.50	0.52	71.28	116.56	81.59	101.50	3.57
30	20.7	34	250.5	1.8	786.4	0.67	56.09	31.38	24.42	8.2	0.01	288.17	0.93	1.50	0.52	66.19	121.65	85.15	96.60	3.40
oct							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	17.1	31	250.1	2.1	787.7	0.76	56.09	26.70	19.50	7.4	0.01	288.06	0.94	1.23	0.52	71.21	116.34	81.44	44.62	1.57
2	17.1	28	250.1	1.4	787.4	0.76	56.09	40.39	19.50	5.8	0.00	287.84	0.94	1.23	0.52	75.65	111.90	78.33	49.53	1.74
3	17.1	27	250.1	1.6	786.7	0.76	56.09	35.36	19.50	5.5	0.00	287.80	0.94	1.23	0.52	76.55	111.01	77.71	50.17	1.77
4	17.1	31	250.1	2.5	787.6	0.76	56.09	22.37	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	46.64	1.64
5	17.1	32	250.1	2.2	788.3	0.76	56.09	25.07	19.50	6.8	0.01	287.98	0.94	1.23	0.52	72.81	114.74	80.32	46.21	1.63
6	17.1	34	250.1	1.8	788.2	0.76	56.09	31.38	19.50	6.8	0.01	287.98	0.94	1.23	0.52	72.81	114.74	80.32	46.56	1.64
7	17.1	31	250.1	2.1	789.1	0.76	56.09	26.92	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	113.35	79.35	47.71	1.68
8	17.1	32	250.1	1.3	788.1	0.76	56.09	42.62	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	47.63	1.68
9	17.1	34	250.1	1.4	789.1	0.76	56.09	39.53	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	113.35	79.35	48.24	1.70
10	17.1	33	250.1	2.1	789	0.76	56.09	26.81	19.50	7.1	0.01	288.02	0.94	1.23	0.52	72.00	115.55	80.88	45.47	1.60
11	17.1	41	250.1	1.6	788.2	0.76	56.09	35.36	19.50	6.4	0.01	287.92	0.94	1.23	0.52	73.92	113.63	79.54	47.82	1.68
12	17.1	37	250.1	1.4	788	0.76	56.09	39.89	19.50	7.4	0.01	288.06	0.94	1.23	0.52	71.21	116.34	81.44	45.48	1.60
13	17.1	34	250.1	2.0	788.9	0.76	56.09	28.38	19.50	7.2	0.01	288.03	0.94	1.23	0.52	71.74	115.82	81.07	45.29	1.59
14	17.1	32	250.1	1.5	788.6	0.76	56.09	37.17	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	47.36	1.67
15	17.1	37	250.1	1.5	788.3	0.76	56.09	37.28	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	113.35	79.35	48.16	1.70
16	17.1	37	250.1	1.6	788.7	0.76	56.09	34.82	19.50	7.1	0.01	288.02	0.94	1.23	0.52	72.00	115.55	80.88	45.94	1.62
17	17.1	50	250.1	1.5	788.6	0.76	56.09	36.86	19.50	7	0.01	288.00	0.94	1.23	0.52	72.27	115.28	80.70	46.33	1.63
18	17.1	68	250.1	1.1	788.6	0.76	56.09	52.13	19.50	10.3	0.01	288.46	0.94	1.23	0.52	64.26	123.30	86.31	39.41	1.39
19	17.1	42	250.1	1.5	788.3	0.76	56.09	38.04	19.50	12.8	0.01	288.81	0.94	1.23	0.52	59.02	128.54	89.98	31.32	1.10
20	17.1	42	250.1	1.5	788.3	0.76	56.09	38.37	19.50	7.7	0.01	288.10	0.94	1.23	0.52	70.43	117.12	81.98	44.61	1.57
21	17.1	35	250.1	1.7	788.3	0.76	56.09	32.15	19.50	6.5	0.01	287.94	0.94	1.23	0.52	73.64	113.91	79.74	47.41	1.67
22	17.1	38	250.1	2.0	788.8	0.76	56.09	27.43	19.50	7.8	0.01	288.11	0.94	1.23	0.52	70.18	117.37	82.16	43.55	1.53
23	17.1	51	250.1	1.6	788.4	0.76	56.09	35.08	19.50	10.6	0.01	288.50	0.94	1.23	0.52	63.60	123.96	86.77	36.69	1.29
24	17.1	57	250.1	1.9	787.8	0.76	56.09	29.80	19.50	11.2	0.01	288.59	0.94	1.23	0.52	62.30	125.25	87.68	34.31	1.21
25	17.1	35	250.1	2.0	787.9	0.76	56.09	27.96	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	46.93	1.65
26	17.1	34	250.1	2.0	788.1	0.76	56.09	27.90	19.50	6.2	0.00	287.90	0.94	1.23	0.52	74.49	113.07	79.15	48.04	1.69
27	17.1	33	250.1	1.9	787.9	0.76	56.09	29.01	19.50	6.2	0.00	287.90	0.94	1.23	0.52	74.49	113.07	79.15	48.09	1.69
28	17.1	37	250.1	1.6	788.1	0.76	56.09	36.05	19.50	7.6	0.01	288.09	0.94	1.23	0.52	70.69	116.86	81.80	44.72	1.57
29	17.1	44	250.1	1.9	788.9	0.76	56.09	29.34	19.50	9.2	0.01	288.31	0.94	1.23	0.52	66.76	120.79	84.55	39.82	1.40
30	17.1	46	250.1	1.2	789.4	0.76	56.09	46.24	19.50	9.1	0.01	288.29	0.94	1.23	0.52	67.00	120.56	84.39	41.71	1.47
31	17.1	51	250.1	1.4	789.4	0.76	56.09	41.02	19.50	10.2	0.01	288.44	0.94	1.23	0.52	64.48	123.08	86.15	38.45	1.35

nov							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	14.6	40	244.5	2.5	789.1	0.88	56.09	22.64	16.62	7.9	0.01	288.13	0.95	1.07	0.52	75.57	107.83	75.48	33.18	1.17
2	14.6	37	244.5	1.5	789.3	0.88	56.09	36.55	16.62	6.6	0.01	287.95	0.95	1.07	0.52	79.29	104.12	72.88	37.85	1.33
3	14.6	35	244.5	1.4	788.9	0.88	56.09	40.89	16.62	6.1	0.00	287.88	0.95	1.07	0.52	80.81	102.59	71.81	39.38	1.39
4	14.6	36	244.5	1.2	788.3	0.88	56.09	45.27	16.62	5.9	0.00	287.85	0.95	1.07	0.52	81.44	101.97	71.38	40.07	1.41
5	14.6	32	244.5	1.7	787.9	0.88	56.09	33.29	16.62	5.1	0.00	287.74	0.95	1.07	0.52	84.06	99.34	69.54	41.77	1.47
6	14.6	39	244.5	2.0	787.5	0.88	56.09	28.26	16.62	6.6	0.01	287.95	0.95	1.07	0.52	79.29	104.12	72.88	37.39	1.32
7	14.6	50	244.5	1.7	788.2	0.88	56.09	32.71	16.62	8.6	0.01	288.25	0.95	1.07	0.52	73.18	110.23	77.16	31.56	1.11
8	14.6	49	244.5	1.8	788.3	0.88	56.09	31.68	16.62	8.5	0.01	288.21	0.95	1.07	0.52	73.96	109.44	76.81	32.30	1.14
9	14.6	38	244.5	1.4	787.8	0.88	56.09	39.65	16.62	7.5	0.01	288.07	0.95	1.07	0.52	76.68	106.72	74.71	35.67	1.26
10	14.6	40	244.5	1.7	787.4	0.88	56.09	33.90	16.62	6.9	0.01	287.99	0.95	1.07	0.52	78.40	105.01	73.50	36.90	1.30
11	14.6	36	244.5	1.6	787.8	0.88	56.09	34.70	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	101.65	71.15	39.93	1.41
12	14.6	30	244.5	1.4	787.7	0.88	56.09	39.29	16.62	6.3	0.00	287.91	0.95	1.07	0.52	80.20	103.21	72.25	38.60	1.37
13	14.6	31	244.5	1.4	786.7	0.88	56.09	39.65	16.62	4.9	0.00	287.72	0.95	1.07	0.52	84.75	98.65	69.06	42.45	1.49
14	14.6	36	244.5	1.5	786.7	0.88	56.09	36.55	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	101.65	71.15	40.00	1.41
15	14.6	42	244.5	1.5	787.1	0.88	56.09	37.71	16.62	6.8	0.01	287.98	0.95	1.07	0.52	78.69	104.71	73.30	37.40	1.32
16	14.6	43	244.5	1.4	786.8	0.88	56.09	39.29	16.62	7.1	0.01	288.02	0.95	1.07	0.52	77.82	105.59	73.91	36.70	1.29
17	14.6	42	244.5	2.1	787.4	0.88	56.09	27.03	16.62	7	0.01	288.01	0.95	1.07	0.52	78.11	105.30	73.71	36.17	1.27
18	14.6	40	244.5	1.9	788.3	0.88	56.09	30.29	16.62	6.1	0.00	287.88	0.95	1.07	0.52	80.81	102.59	71.81	38.91	1.37
19	14.6	40	244.5	1.6	788.6	0.88	56.09	35.46	16.62	6.2	0.00	287.89	0.95	1.07	0.52	80.50	102.90	72.03	38.88	1.37
20	14.6	42	244.5	1.4	788.6	0.88	56.09	40.89	16.62	6.3	0.00	287.91	0.95	1.07	0.52	80.20	103.21	72.25	38.67	1.37
21	14.6	42	244.5	1.6	788.7	0.88	56.09	35.17	16.62	5.7	0.00	287.83	0.95	1.07	0.52	82.08	101.33	70.93	40.21	1.42
22	14.6	34	244.5	1.6	787.9	0.88	56.09	34.89	16.62	4.8	0.00	287.67	0.95	1.07	0.52	85.81	97.60	68.32	43.15	1.52
23	14.6	33	244.5	1.6	787	0.88	56.09	35.36	16.62	4.5	0.00	287.66	0.95	1.07	0.52	86.17	97.24	68.07	43.42	1.53
24	14.6	34	244.5	1.8	787.7	0.88	56.09	31.06	16.62	5	0.00	287.73	0.95	1.07	0.52	84.41	99.00	69.30	41.99	1.48
25	14.6	37	244.5	1.6	788.3	0.88	56.09	35.94	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	101.65	71.15	39.97	1.41
26	14.6	39	244.5	1.7	788.8	0.88	56.09	33.21	16.62	5.8	0.00	287.84	0.95	1.07	0.52	81.76	101.65	71.15	39.86	1.40
27	14.6	36	244.5	2.0	788.3	0.88	56.09	28.63	16.62	5.4	0.00	287.78	0.95	1.07	0.52	83.06	100.35	70.24	40.81	1.44
28	14.6	33	244.5	1.5	788.2	0.88	56.09	36.34	16.62	4.8	0.00	287.70	0.95	1.07	0.52	85.10	98.31	68.81	42.64	1.50
29	14.6	32	244.5	2.0	788.7	0.88	56.09	28.26	16.62	4.2	0.00	287.62	0.95	1.07	0.52	87.28	96.13	67.29	44.17	1.56
30	14.6	37	244.5	1.6	789.2	0.88	56.09	34.61	16.62	4.7	0.00	287.69	0.95	1.07	0.52	85.45	97.95	68.57	42.87	1.51
dec							56.09	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	12.1	49	223.9	1.9	788.8	0.85	56.09	29.74	14.12	6.2	0.00	287.89	0.96	0.93	0.52	75.68	92.26	64.58	30.07	1.06
2	12.7	38	223.9	1.6	787.9	0.85	56.09	35.95	14.69	4.8	0.00	287.70	0.96	0.96	0.52	80.66	87.26	61.08	35.96	1.27
3	13.2	34	223.9	1.3	787.4	0.85	56.09	42.76	15.17	4.3	0.00	287.63	0.96	0.99	0.52	82.96	84.97	59.48	38.76	1.36
4	13	31	223.9	1.7	787.5	0.85	56.09	33.55	14.98	4.1	0.00	287.61	0.96	0.98	0.52	83.45	84.49	59.14	38.73	1.36
5	14	28	223.9	1.7	786.7	0.85	56.09	33.81	15.99	4	0.00	287.59	0.95	1.04	0.52	84.99	82.95	58.07	41.92	1.48
6	14.1	33	223.9	1.1	788.3	0.85	56.09	49.75	16.09	4.5	0.00	287.66	0.95	1.04	0.52	83.30	84.63	59.24	40.78	1.43
7	13.7	29	223.9	1.7	789.2	0.85	56.09	33.55	15.68	4.2	0.00	287.62	0.96	1.02	0.52	83.90	84.03	58.82	40.48	1.42
8	14.3	30	223.9	1.6	788.6	0.85	56.09	36.05	16.30	4.3	0.00	287.63	0.95	1.05	0.52	84.24	83.69	58.58	41.97	1.48
9	13.7	34	223.9	1.8	789.2	0.85	56.09	31.61	15.68	5.1	0.00	287.74	0.96	1.02	0.52	80.81	87.12	60.99	37.99	1.34
10	12.1	34	223.9	1.1	789	0.85	56.09	51.31	14.12	4.6	0.00	287.67	0.96	0.93	0.52	80.67	87.27	61.09	35.11	1.24
11	12	40	223.9	1.7	788.3	0.85	56.09	33.38	14.03	5.2	0.00	287.76	0.96	0.92	0.52	78.60	89.34	62.54	32.81	1.15
12	10	44	223.9	1.6	787.6	0.85	56.09	30.57	12.28	5.1	0.00	287.74	0.97	0.82	0.52	76.73	91.21	63.85	27.58	0.97
13	12	37	223.9	1.3	786.6	0.85	56.09	42.90	14.03	4.4	0.00	287.65	0.96	0.92	0.52	81.24	86.70	60.69	35.23	1.24
14	13.4	34	223.9	1.4	787.6	0.85	56.09	40.01	15.37	5.1	0.00	287.74	0.95	1.00	0.52	80.48	87.46	61.22	37.22	1.31
15	14.2	34	223.9	1.8	788.4	0.85	56.09	31.91	16.19	5.3	0.00	287.77	0.95	1.05	0.52	80.73	87.21	61.05	38.96	1.37
16	13.2	39	223.9	1.7	788.7	0.85	56.09	32.88	15.17	5.6	0.00	287.81	0.96	0.99	0.52	78.67	89.27	62.49	35.13	1.24
17	12.7	43	223.9	1.6	789.8	0.85	56.09	31.45	14.69	6.3	0.00	287.91	0.96	0.98	0.52	76.03	91.91	64.34	31.61	1.11
18	12.1	49	223.9	1.9	790.7	0.85	56.09	30.08	14.12	6.6	0.01	287.95	0.96	0.93	0.52	74.54	93.40	65.38	28.92	1.02
19	10.6	43	223.9	1.7	789.8	0.85	56.09	33.29	12.78	5.2	0.00	287.76	0.97	0.85	0.52	77.07	90.87	63.61	28.99	1.02
20	10.6	37	223.9	1.5	788.2	0.85	56.09	38.15	12.78	4.4	0.00	287.65	0.97	0.85	0.52	79.65	88.28	61.80	31.44	1.11
21	12.5	40	223.9	1.3	787.4	0.85	56.09	44.21	14.49	5.7	0.00	287.83	0.96	0.95	0.52	77.59	90.34	63.24	33.21	1.17
22	14.5	38	223.9	2.3	788.1	0.85	56.09	24.10	16.51	6	0.00	287.87	0.95	1.07	0.52	78.86	89.07	62.35	37.79	1.33
23	15.5	40	223.9	1.6	788.3	0.85	56.09	34.62	17.61	6.8	0.01	287.96	0.96	1.13	0.52	77.57	90.37	63.26	39.02	1.37
24	16	45	223.9	1.6	788.1	0.85	56.09	35.36	18.18	7.8	0.01	288.12	0.95	1.16	0.52	75.28	92.66	64.86	38.02	1.34
25	15.5	47	223.9	2.0	788.6	0.85	56.09	27.43	17.61	7.9	0.01	288.13	0.95	1.13	0.52	74.49	93.44	65.41	35.73	1.26
26	14.8	55	223.9	2.0	791.3	0.85	56.09	28.45	16.84	9	0.01	288.28	0.95	1.08	0.52	70.93	97.00	67.90	30.29	1.07
27	13	58	223.9	1.9	790.9	0.85	56.09	30.22	14.98	8.3	0.01	288.18	0.96	0.98	0.52	70.92	97.02	67.91	26.68	0.94
28	13.3	46	223.9	1.8	788.6	0.85	56.09	31.30	15.27	6.2	0.00	287.89	0.96	0.99	0.52	76.96	90.98	63.68	33.68	1.19
29	12.2	38	223.9	1.2	788.8	0.85	56.09	47.41	14.21	4.8	0.00	287.70	0.96	0.93	0.52	80.11	87.82	61.48	34.80	1.22
30	11.4	27	223.9	1.6	789.8	0.85	56.09	35.56	13.48	3.2	0.00	287.48	0.96	0.89	0.52	84.97	82.98	58.07	36.81	1.30
31	11.1	32	223.9	2.3	790.2	0.85	56.09	24.69	13.21	3.7	0.00	287.55	0.97	0.88	0.52	82.70	85.24	59.67	34.49	1.21

1993	mean temp mean C	rh %	radiation Langley	wind speed m/s	pressure mb	sunshine fraction	Aerodynamic Resistance (ln((z-d)/zo)	ra m/s t2/f2	e*	ea measured	spec humid kgwater kg	moist air j/kg/k	air density kg/m3	gradient mb/C	psychrom mb/k	Rn w/m2	Rn** W/m2	Rn-G W/m2	final P M equ	actual evap mm
jan																				
1	15.6	47	233.3	2.1	790	0.86	49.47	23.13	17.72	7.9	0.01	288.13	0.95	1.13	0.52	75.27	99.69	69.78	29.73	1.05
2	15.9	42	233.3	1.7	789.3	0.86	49.47	29.59	18.07	7.1	0.01	288.02	0.95	1.15	0.52	77.83	97.13	67.99	32.93	1.16
3	16.6	48	233.3	2.5	788.2	0.86	49.47	19.90	18.89	6.5	0.01	288.21	0.94	1.20	0.52	74.69	100.27	70.19	31.00	1.09
4	16.4	42	233.3	1.5	787.1	0.86	49.47	32.06	18.65	7.3	0.01	288.05	0.94	1.19	0.52	77.80	97.17	68.02	34.07	1.20
5	16	32	233.3	1.3	786.3	0.86	49.47	37.23	18.18	4.9	0.00	287.72	0.94	1.16	0.52	84.88	90.08	63.06	36.40	1.35
6	15	27	233.3	1.7	788.7	0.86	49.47	29.98	17.05	4.2	0.00	287.62	0.95	1.10	0.52	86.21	88.76	62.13	37.09	1.31
7	14.7	31	233.3	1.3	788.5	0.86	49.47	37.23	16.73	4.6	0.00	287.67	0.95	1.08	0.52	84.41	90.56	63.39	35.60	1.25
8	16	33	233.3	1.5	787.1	0.86	49.47	32.97	18.18	4.9	0.00	287.72	0.95	1.16	0.52	84.88	90.08	63.06	38.30	1.35
9	16.3	38	233.3	1.5	787.5	0.86	49.47	32.97	18.53	6	0.00	287.87	0.94	1.18	0.52	81.59	93.38	65.36	36.71	1.29
10	15.5	39	233.3	1.7	787.3	0.86	49.47	28.85	17.61	5.7	0.00	287.83	0.95	1.13	0.52	81.64	93.32	65.33	34.99	1.23
11	15.3	49	233.3	1.6	786.6	0.86	49.47	31.45	17.39	7.2	0.01	288.04	0.95	1.11	0.52	76.90	98.06	68.64	31.14	1.10
12	15.8	48	233.3	1.4	785.9	0.86	49.47	34.14	17.95	8.3	0.01	288.19	0.94	1.15	0.52	74.40	100.56	70.39	30.26	1.07
13	15.8	58	233.3	2.2	787.3	0.86	49.47	22.63	17.95	10.1	0.01	288.43	0.94	1.15	0.52	69.84	105.12	73.59	24.96	0.88
14	12.5	68	233.3	1.6	787.3	0.86	49.47	30.77	14.49	9.7	0.01	288.38	0.96	0.95	0.52	67.64	107.32	75.13	17.78	0.63
15	11.5	70	233.3	1.7	786.5	0.86	49.47	28.71	13.57	8	0.01	288.15	0.96	0.90	0.52	70.83	104.13	72.89	19.18	0.68
16	12.1	60	233.3	1.6	786.9	0.86	49.47	31.28	14.12	7.9	0.01	288.13	0.96	0.93	0.52	71.69	103.27	72.29	21.13	0.74
17	12.8	52	233.3	1.1	787.4	0.86	49.47	44.39	14.78	7.4	0.01	288.06	0.96	0.97	0.52	73.73	101.24	70.87	25.12	0.88
18	12.4	41	233.3	1.1	787.2	0.86	49.47	46.16	14.40	5.6	0.00	287.81	0.96	0.94	0.52	78.50	96.47	67.53	28.19	0.99
19	14	44	233.3	2.7	787.1	0.86	49.47	18.23	15.99	6.7	0.01	287.97	0.95	1.04	0.52	78.95	96.02	68.61	27.84	0.98
20	13.9	43	233.3	1.3	787.5	0.86	49.47	37.23	15.88	6.1	0.00	287.88	0.95	1.03	0.52	78.61	96.35	67.45	30.25	1.06
21	14.2	49	233.3	2.5	787.5	0.86	49.47	19.76	16.19	7.7	0.01	288.10	0.95	1.05	0.52	74.38	100.60	70.42	26.00	0.92
22	14.7	60	233.3	1.7	788.4	0.86	49.47	29.22	16.73	9.7	0.01	288.38	0.95	1.08	0.52	69.75	105.22	73.65	23.47	0.83
23	15.3	61	233.3	1.9	788.4	0.86	49.47	25.59	17.39	10.4	0.01	288.47	0.95	1.11	0.52	68.65	106.32	74.42	23.11	0.81
24	14.7	62	233.3	1.5	787	0.86	49.47	33.26	16.73	10.3	0.01	288.46	0.95	1.08	0.52	68.31	106.65	74.66	22.54	0.79
25	13.3	71	233.3	1.6	788.8	0.86	49.47	31.19	15.27	10.6	0.01	288.50	0.96	0.99	0.52	66.31	108.66	76.06	17.78	0.63
26	12.1	74	233.3	1.8	788.8	0.86	49.47	28.15	14.12	10.7	0.01	288.51	0.96	0.93	0.52	64.98	109.99	76.99	14.00	0.49
27	13.4	67	233.3	1.0	790.1	0.86	49.47	48.09	15.37	9.9	0.01	288.40	0.96	1.00	0.52	68.02	106.94	74.86	21.52	0.76
28	13.8	60	233.3	1.2	790	0.86	49.47	41.81	15.78	8.7	0.01	288.24	0.95	1.02	0.52	71.34	103.62	72.54	24.56	0.86
29	14.8	56	233.3	2.0	789.8	0.86	49.47	24.66	16.84	8.6	0.01	288.22	0.95	1.08	0.52	72.60	102.37	71.66	25.90	0.91
30	16.2	52	233.3	2.2	788.4	0.86	49.47	22.41	18.42	9.2	0.01	288.31	0.94	1.17	0.52	72.47	102.50	71.75	28.31	1.00
31	17.5	49	233.3	2.5	787.2	0.86	49.47	19.90	20.00	8.8	0.01	288.26	0.94	1.26	0.52	74.82	100.14	70.10	33.09	1.16
feb							49.47				ERR	ERR	ERR	0.00	0.00	21.34	-21.34	-14.94	ERR	0.00
1	17.7	46	237.5	2.2	786.6	0.75	49.47	22.99	20.25	8.8	0.01	288.26	0.94	1.27	0.52	67.60	110.50	77.35	34.54	1.22
2	18.1	54	237.5	1.2	786	0.75	49.47	41.22	20.77	10.4	0.01	288.48	0.94	1.30	0.52	64.28	113.81	79.67	34.06	1.20
3	17.2	57	237.5	1.1	785.8	0.75	49.47	46.53	19.62	10.9	0.01	288.55	0.94	1.24	0.52	62.41	115.68	80.98	30.81	1.08
4	16.5	58	237.5	1.8	785.7	0.75	49.47	27.48	18.77	10.7	0.01	288.52	0.94	1.19	0.52	62.23	115.86	81.10	26.80	0.94
5	16.5	61	237.5	1.7	785.9	0.75	49.47	28.85	18.77	11.4	0.01	288.62	0.94	1.19	0.52	60.76	117.33	82.13	25.35	0.89
6	12.8	70	237.5	2.0	786.5	0.75	49.47	24.45	14.78	10.4	0.01	288.48	0.95	0.97	0.52	59.73	118.36	82.85	16.49	0.58
7	8.7	72	237.5	2.2	788.1	0.75	49.47	22.45	11.25	8.1	0.01	288.16	0.97	0.76	0.52	61.12	116.97	81.88	12.20	0.43
8	12.8	58	237.5	1.4	787.3	0.75	49.47	34.14	14.78	8.2	0.01	288.17	0.95	0.97	0.52	64.52	113.57	79.50	23.05	0.81
9	13.6	57	237.5	2.2	787.2	0.75	49.47	22.72	15.58	8.6	0.01	288.23	0.95	1.01	0.52	64.32	113.77	79.64	22.86	0.80
10	14.5	62	237.5	2.1	786.5	0.75	49.47	23.55	16.51	9.7	0.01	288.38	0.95	1.07	0.52	62.66	115.43	80.80	22.78	0.80
11	14.2	67	237.5	2.3	786.7	0.75	49.47	21.86	16.19	10.2	0.01	288.45	0.95	1.05	0.52	61.33	116.76	81.73	20.44	0.72
12	13.4	81	237.5	2.1	788.1	0.75	49.47	23.31	15.37	12.3	0.01	288.74	0.95	1.00	0.52	56.46	121.64	85.14	13.21	0.46
13	16.4	61	237.5	2.3	787.7	0.75	49.47	21.10	18.65	10.5	0.01	288.49	0.94	1.19	0.52	62.58	115.51	80.86	26.10	0.92
14	16.4	49	237.5	2.0	787.3	0.75	49.47	24.55	18.65	8.7	0.01	288.24	0.94	1.19	0.52	66.63	111.46	78.02	30.87	1.09
15	17.1	49	237.5	1.3	786.9	0.75	49.47	37.23	19.50	8.8	0.01	288.26	0.94	1.23	0.52	67.04	111.05	77.74	34.00	1.20
16	17.2	38	237.5	1.9	786.4	0.75	49.47	25.99	19.62	7.3	0.01	288.05	0.94	1.24	0.52	70.86	107.23	75.06	65.66	2.31
17	16.5	45	237.5	2.1	786.3	0.75	49.47	23.55	18.77	7.9	0.01	288.13	0.94	1.19	0.52	68.66	109.43	76.60	59.61	2.10
18	17.4	42	237.5	2.2	786.8	0.75	49.47	22.11	19.87	7.7	0.01	288.10	0.94	1.25	0.52	70.03	108.06	75.65	65.44	2.30
19	17.2	37	237.5	2.6	787.6	0.75	49.47	19.33	19.62	6.6	0.01	287.95	0.94	1.24	0.52	72.74	105.35	73.75	69.53	2.45
20	18	24	237.5	2.7	787.2	0.75	49.47	18.23	20.64	4.4	0.00	287.65	0.94	1.30	0.52	80.26	97.83	68.48	84.05	2.96
21	18.8	26	237.5	2.5	786.5	0.75	49.47	20.00	21.70	4.8	0.00	287.70	0.94	1.35	0.52	79.80	98.29	68.80	86.26	3.04
22	18.2	31	237.5	2.2	787.1	0.75	49.47	22.63	20.90	6.2	0.00	287.90	0.94	1.31	0.52	74.87	103.22	72.25	76.20	2.68
23	17.8	42	237.5	1.8	787.6	0.75	49.47	27.15	20.38	8.4	0.01	288.20	0.94	1.28	0.52	68.66	109.43	76.60	64.21	2.26
24	16.8	55	237.5	2.7	788	0.75	49.47	18.32	19.13	9.9	0.01	288.41	0.94	1.21	0.52	64.24	113.85	79.70	52.42	1.85
25	13.9	51	237.5	1.7	789.2	0.75	49.47	29.82	15.88	7.8	0.01	288.11	0.95	1.03	0.52	66.47	111.62	78.13	47.14	1.66
26	14.4	34	237.5	1.8	788.6	0.75	49.47	26.96	16.41	5.3	0.00	287.77	0.95	1.06	0.52	73.59	104.50	73.15	80.15	2.12
27	14.1	29	237.5	1.2	788	0.75	49.47	40.92	16.09	4	0.00	287.59	0.96	1.04	0.52	77.37	100.72	70.51	62.71	2.21
28	14.4	29	237.5	2.2	787.7	0.75	49.47	22.94	16.41	4.1	0.00	287.61	0.95	1.06	0.52	77.35	100.74	70.52	65.82	2.32

mar								49.47												ERR	0.00
	1	14.6	26	256.0	1.5	788.4	0.72	49.47	33.26	16.62	3.7	0.00	287.55	0.95	1.07	0.52	76.58	115.40	80.78	68.74	2.42
	2	14.1	25	256.0	1.8	788.9	0.72	49.47	27.03	16.09	3.6	0.00	287.54	0.95	1.04	0.52	76.39	115.58	80.91	67.53	2.38
	3	14	25	256.0	1.5	789.1	0.72	49.47	33.16	15.99	3.6	0.00	287.54	0.96	1.04	0.52	76.29	115.69	80.98	66.51	2.34
	4	14.7	28	256.0	1.8	787.9	0.72	49.47	27.28	16.73	4.5	0.00	287.66	0.95	1.06	0.52	74.07	117.90	82.53	66.47	2.34
	5	17.1	33	256.0	2.3	785.5	0.72	49.47	21.77	19.50	5.7	0.00	287.63	0.94	1.23	0.52	72.94	119.04	83.33	74.00	2.60
	6	18.2	36	256.0	2.5	785	0.72	49.47	19.63	20.90	7.2	0.01	288.04	0.93	1.31	0.52	69.95	122.03	85.42	73.87	2.60
	7	19.1	43	256.0	1.7	785.8	0.72	49.47	29.59	22.11	9	0.01	288.29	0.93	1.38	0.52	66.37	125.61	87.93	70.71	2.49
	8	19.5	46	256.0	1.6	787	0.72	49.47	30.61	22.67	10.2	0.01	288.45	0.93	1.41	0.52	64.00	127.98	89.59	68.28	2.40
	9	19.9	50	256.0	2.0	787.6	0.72	49.47	24.30	23.24	10.7	0.01	288.52	0.93	1.44	0.52	63.25	128.73	90.11	68.81	2.42
	10	19.9	47	256.0	2.1	787.9	0.72	49.47	23.46	23.24	10.5	0.01	288.49	0.93	1.44	0.52	63.69	128.29	89.80	69.66	2.45
	11	20.1	43	256.0	2.3	788.1	0.72	49.47	21.18	23.53	9.8	0.01	288.39	0.93	1.45	0.52	65.42	126.55	88.59	73.97	2.60
	12	20	51	256.0	1.8	787.9	0.72	49.47	26.90	23.38	11.3	0.01	288.60	0.93	1.44	0.52	62.05	129.93	90.95	86.96	2.36
	13	18.9	49	256.0	1.5	788.2	0.72	49.47	32.15	21.84	10.3	0.01	288.46	0.94	1.36	0.52	63.26	128.72	90.10	64.49	2.27
	14	19	40	256.0	1.6	788	0.72	49.47	31.02	21.97	8.3	0.01	288.19	0.94	1.37	0.52	67.95	124.03	86.82	72.76	2.56
	15	19	47	256.0	1.4	787.5	0.72	49.47	35.18	21.97	9.7	0.01	288.38	0.93	1.37	0.52	64.67	127.30	89.11	67.28	2.37
	16	19	52	256.0	2.6	786.1	0.72	49.47	19.17	21.97	11.1	0.01	288.58	0.93	1.37	0.52	61.63	130.35	91.24	61.50	2.16
	17	18.3	52	256.0	1.6	785	0.72	49.47	30.53	21.03	10.7	0.01	288.52	0.93	1.32	0.52	61.88	130.10	91.07	59.57	2.10
	18	19.8	52	256.0	3.0	785.4	0.72	49.47	16.49	23.09	11.5	0.01	288.63	0.93	1.43	0.52	61.46	130.52	91.36	64.76	2.28
	19	20.1	49	256.0	2.2	786.8	0.72	49.47	22.76	23.53	10.7	0.01	288.52	0.93	1.45	0.52	63.42	128.55	89.99	70.10	2.47
	20	19.3	43	256.0	2.0	787.6	0.72	49.47	25.25	22.39	8.3	0.01	288.19	0.93	1.39	0.52	68.23	123.75	86.63	74.99	2.64
	21	18.8	48	256.0	2.0	787.8	0.72	49.47	24.45	21.70	9.3	0.01	288.32	0.94	1.35	0.52	65.40	126.57	88.60	68.02	2.39
	22	20.1	41	256.0	2.1	787.9	0.72	49.47	23.65	23.53	9	0.01	288.28	0.93	1.45	0.52	67.28	124.70	87.29	77.07	2.71
	23	19.2	40	256.0	1.8	789	0.72	49.47	28.15	22.25	8.5	0.01	288.21	0.94	1.38	0.52	67.65	124.33	87.03	73.34	2.58
	24	19.6	40	256.0	2.6	788.7	0.72	49.47	18.70	22.81	8.7	0.01	288.24	0.93	1.41	0.52	67.54	124.44	87.11	75.83	2.67
	25	19.6	45	256.0	2.3	787.9	0.72	49.47	21.37	22.81	9.7	0.01	288.38	0.93	1.41	0.52	65.20	126.77	88.74	71.27	2.51
	26	19.6	43	256.0	2.0	787.2	0.72	49.47	25.31	22.81	9.3	0.01	288.32	0.93	1.41	0.52	66.12	125.85	88.10	72.68	2.56
	27	18.4	56	256.0	2.3	787.1	0.72	49.47	21.37	21.16	11.4	0.01	288.61	0.93	1.32	0.52	60.50	131.48	92.03	56.64	1.99
	28	16	72	256.0	2.2	787.7	0.72	49.47	22.63	18.18	12.7	0.01	288.79	0.94	1.16	0.52	56.01	135.96	95.17	37.21	1.31
	29	16.2	69	256.0	2.2	788.2	0.72	49.47	22.19	18.42	12.1	0.01	288.71	0.94	1.17	0.52	57.32	134.66	94.26	40.89	1.44
	30	16.9	70	256.0	3.1	788	0.72	49.47	15.81	19.25	12.5	0.01	288.76	0.94	1.22	0.52	57.10	134.88	94.41	41.80	1.47
	31	17.1	65	256.0	2.3	787.3	0.72	49.47	21.37	19.50	11.9	0.01	288.68	0.94	1.23	0.52	58.43	133.55	93.48	46.76	1.65
apr								49.47				ERR	ERR	ERR	0.00	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	19	53	260.4	2.7	786.7	0.67	49.47	18.32	21.97	11.2	0.01	288.59	0.93	1.37	0.52	58.25	137.05	95.94	61.57	2.17
	2	17.1	67	260.4	2.3	786.7	0.67	49.47	21.37	19.50	12.6	0.01	288.78	0.94	1.23	0.52	54.12	141.18	98.83	44.24	1.56
	3	16.2	73	260.4	2.1	787	0.67	49.47	23.89	18.42	12.7	0.01	288.79	0.94	1.17	0.52	53.27	142.03	99.42	39.21	1.38
	4	17.1	67	260.4	1.6	786.9	0.67	49.47	30.37	19.50	12.3	0.01	288.74	0.94	1.23	0.52	54.67	140.63	98.44	47.25	1.66
	5	15.9	77	260.4	2.8	788.2	0.67	49.47	17.75	18.07	13.5	0.01	288.90	0.94	1.15	0.52	51.64	143.66	100.56	32.18	1.13
	6	15.1	82	260.4	2.6	788.3	0.67	49.47	18.92	17.16	13.5	0.01	288.90	0.95	1.10	0.52	51.08	144.23	100.96	28.01	0.99
	7	17.9	70	260.4	2.0	786.7	0.67	49.47	25.36	20.51	13.5	0.01	288.91	0.94	1.29	0.52	53.09	142.22	99.55	45.92	1.62
	8	18	69	260.4	2.4	786.5	0.67	49.47	20.32	20.64	13.8	0.01	288.95	0.93	1.30	0.52	52.63	142.68	99.87	44.09	1.55
	9	18.1	66	260.4	1.3	787.2	0.67	49.47	38.47	20.77	13.2	0.01	288.86	0.94	1.30	0.52	53.77	141.53	99.07	50.61	1.78
	10	18.3	68	260.4	2.0	787.9	0.67	49.47	24.55	21.03	13.7	0.01	288.93	0.94	1.32	0.52	53.02	142.28	99.60	47.29	1.66
	11	17.5	69	260.4	2.1	787.7	0.67	49.47	23.31	20.00	13.1	0.01	288.85	0.94	1.26	0.52	53.51	141.79	99.25	44.81	1.58
	12	16.9	71	260.4	2.3	787.1	0.67	49.47	21.90	19.25	13.1	0.01	288.85	0.94	1.22	0.52	53.07	142.23	99.56	40.97	1.44
	13	15.6	82	260.4	2.1	788.1	0.67	49.47	24.04	17.72	14	0.01	288.97	0.94	1.13	0.52	50.58	144.73	101.31	30.18	1.06
	14	14.5	83	260.4	2.7	789.7	0.67	49.47	18.12	16.51	13.7	0.01	288.93	0.95	1.07	0.52	50.31	144.99	101.49	23.46	0.83
	15	12.3	93	260.4	2.7	790.2	0.67	49.47	18.44	14.31	13.3	0.01	288.87	0.96	0.94	0.52	49.45	145.85	102.10	13.94	0.49
	16	14.1	81	260.4	2.2	789.5	0.67	49.47	22.19	16.09	12.8	0.01	288.80	0.95	1.04	0.52	51.57	143.73	100.61	26.85	0.95
	17	13	81	260.4	2.8	788.3	0.67	49.47	17.75	14.98	12	0.01	288.69	0.95	0.98	0.52	52.18	143.13	100.19	23.51	0.83
	18	14.6	72	260.4	1.7	787.8	0.67	49.47	28.64	16.62	11.6	0.01	288.64	0.95	1.07	0.52	54.08	141.22	98.86	36.47	1.28
	19	13.9	74	260.4	2.6	788.9	0.67	49.47	19.14	15.88	11.4	0.01	288.61	0.95	1.03	0.52	53.92	141.38	98.97	31.40	1.11
	20	16.2	67	260.4	1.5	787.6	0.67	49.47	33.26	18.42	11.8	0.01	288.67	0.94	1.17	0.52	54.92	140.39	98.27	44.89	1.58
	21	16.8	62	260.4	1.6	787	0.67	49.47	30.37	21.70	12.9	0.01	288.82	0.93	1.35	0.52	54.84	140.46	98.32	54.54	1.92
	22	19.1	61	260.4	2.9	786.3	0.67	49.47	16.85	22.11	12.6	0.01	288.78	0.93	1.38	0.52	55.63	139.68	97.77	55.75	1.96
	23	20.3	60	260.4	2.0	786.1	0.67	49.47	25.20	23.82	13.3	0.01	288.88	0.93	1.47	0.52	55.23	140.07	98.05	61.48	2.16
	24	19.9	57	260.4	3.1	785.9	0.67	49.47	15.87	23.24	12.5	0.01	288.77	0.93	1.44	0.52	56.43	138.87	97.21	61.37	2.16
	25	18.8	63	260.4	1.9	785.4	0.67	49.47	26.47	21.70	13.1	0.01	288.85	0.93	1.35	0.52	54.47	140.83	98.58	53.17	1.87
	26	19.6	55	260.4	1.4	785.3	0.67	49.47	36.41	22.81	11.7	0.01	288.66	0.93	1.41	0.52	57.74	137.56	96.29	64.26	2.26
	27	18.8	60	260.4	1.8	785.7	0.67	49.47	27.94	21.70	12.5	0.01	288.77	0.93	1.35	0.52	55.59	139.72	97.80	55.82	1.96
	28	18.6	61	260.4	1.7	785.8	0.67	49.47	29.44	21.43	12.6	0.01	288.78	0.93	1.34	0.52	55.25	140.06	98.04	54.44	1.92
	29	17.7	67	260.4	1.0	785.6	0.67	49.47	47.30	20.25	12.9	0.01	288.63	0.93	1.27	0.52	54.02	141.28	98.90	50.86	1.79
	30	18.3	62	260.4	1.7	785.5	0.67	49.47	29.07	21.03	12	0.01	288.70	0.93	1.32	0.52	56.15	139.16	97.41	55.06	1.94

may							49.47	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	20.3	53	276.7	1.4	786.1	0.72	49.47	35.73	23.82	11.7	0.01	288.66	0.93	1.47	0.52	61.46	146.08	102.26	69.62	2.45
2	20.1	49	276.7	2.6	786.9	0.72	49.47	19.23	23.53	10.7	0.01	288.52	0.93	1.45	0.52	63.42	144.12	100.88	71.70	2.52
3	18.2	62	276.7	3.0	787.8	0.72	49.47	16.37	20.90	12.8	0.01	288.81	0.94	1.31	0.52	57.54	150.00	105.00	49.68	1.75
4	19	59	276.7	2.9	786.6	0.72	49.47	16.92	21.97	12	0.01	288.70	0.93	1.37	0.52	59.77	147.77	103.44	58.58	2.06
5	20.2	55	276.7	1.8	785.5	0.72	49.47	27.03	23.67	11.8	0.01	288.67	0.93	1.46	0.52	61.17	146.37	102.46	68.15	2.40
6	19.6	58	276.7	2.9	785.4	0.72	49.47	16.90	22.81	12	0.01	288.70	0.93	1.41	0.52	60.26	147.28	103.10	62.50	2.20
7	19.7	61	276.7	2.3	785.5	0.72	49.47	21.14	22.95	13.2	0.01	288.87	0.93	1.42	0.52	57.95	149.59	104.71	58.51	2.06
8	21.4	42	276.7	1.7	785.8	0.72	49.47	29.22	25.49	10	0.01	288.42	0.92	1.56	0.52	66.13	141.41	98.99	82.53	2.81
9	20.1	44	276.7	1.2	787.2	0.72	49.47	40.92	23.53	9.8	0.01	288.39	0.93	1.45	0.52	65.42	142.12	99.48	75.22	2.65
10	21.1	43	276.7	1.6	785.9	0.72	49.47	31.70	25.02	10.4	0.01	288.48	0.93	1.53	0.52	64.96	142.58	99.81	79.07	2.78
11	21.8	41	276.7	3.3	785.2	0.72	49.47	15.11	26.12	10.4	0.01	288.48	0.92	1.59	0.52	65.58	141.96	99.38	84.79	2.98
12	19.6	64	276.7	3.6	785.2	0.72	49.47	13.90	22.81	14.2	0.01	289.01	0.93	1.41	0.52	55.96	151.58	106.11	51.85	1.83
13	17.6	80	276.7	3.3	787.1	0.72	49.47	14.85	20.13	15	0.01	289.11	0.94	1.27	0.52	53.01	154.53	108.17	35.15	1.24
14	17.3	75	276.7	3.2	788.6	0.72	49.47	15.25	19.75	13.9	0.01	288.96	0.94	1.25	0.52	54.77	152.77	106.94	38.57	1.36
15	17.8	64	276.7	1.6	789.4	0.72	49.47	31.62	20.38	13.2	0.01	288.86	0.94	1.28	0.52	56.46	151.08	105.76	48.93	1.72
16	16.8	76	276.7	2.7	788.6	0.72	49.47	18.32	19.13	14.4	0.01	289.03	0.94	1.21	0.52	53.49	154.05	107.83	34.23	1.21
17	18.3	67	276.7	2.4	786.6	0.72	49.47	20.98	21.03	13.7	0.01	288.93	0.93	1.32	0.52	55.91	151.64	106.15	47.41	1.67
18	19.4	56	276.7	1.1	786.6	0.72	49.47	43.71	22.53	11.7	0.01	288.66	0.93	1.40	0.52	60.71	146.83	102.78	65.07	2.29
19	20.2	49	276.7	1.7	787	0.72	49.47	26.78	23.67	10.2	0.01	288.45	0.93	1.46	0.52	64.61	142.93	100.05	74.47	2.62
20	20.3	43	276.7	1.8	787	0.72	49.47	30.86	23.82	9.1	0.01	288.30	0.93	1.47	0.52	67.23	140.32	98.22	79.20	2.79
21	20.6	38	276.7	1.3	786.9	0.72	49.47	37.96	24.27	8.5	0.01	288.21	0.93	1.49	0.52	68.95	138.59	97.01	82.55	2.91
22	21.1	35	276.7	1.3	786.8	0.72	49.47	38.73	25.02	8.4	0.01	288.20	0.93	1.53	0.52	69.67	137.87	96.51	85.59	3.01
23	21.3	36	276.7	1.8	787.2	0.72	49.47	27.68	25.33	9.1	0.01	288.30	0.93	1.55	0.52	68.15	139.39	97.56	85.46	3.01
24	20.8	35	276.7	1.1	786.8	0.72	49.47	43.71	24.57	8.2	0.01	288.17	0.93	1.51	0.52	69.89	137.66	96.36	84.10	2.96
25	20.1	33	276.7	1.2	786.4	0.72	49.47	39.80	23.53	7.4	0.01	288.06	0.93	1.45	0.52	71.26	136.28	95.40	83.43	2.94
26	21.2	33	276.7	1.5	786.5	0.72	49.47	33.18	25.18	7.8	0.01	288.12	0.93	1.54	0.52	71.29	136.25	95.38	88.97	3.13
27	21.9	32	276.7	1.7	787.3	0.72	49.47	29.74	26.28	8.2	0.01	288.17	0.93	1.60	0.52	70.94	136.61	95.62	92.24	3.25
28	22.6	29	276.7	1.6	787.1	0.72	49.47	30.77	27.42	7.6	0.01	288.09	0.92	1.66	0.52	73.18	134.36	94.05	96.45	3.47
29	21.4	34	276.7	2.6	786.6	0.72	49.47	19.04	25.49	8.3	0.01	288.19	0.93	1.56	0.52	70.20	137.34	96.14	90.62	3.19
30	21.7	35	276.7	1.2	785.7	0.72	49.47	42.74	25.96	8.7	0.01	288.24	0.92	1.58	0.52	69.49	138.05	96.63	87.44	3.08
31	22.6	47	276.7	2.0	785.5	0.72	49.47	24.66	27.42	12.1	0.01	288.71	0.92	1.66	0.52	62.56	144.98	101.49	82.52	2.90
jun							49.47	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
1	22.7	43	257.0	1.7	786.5	0.64	49.47	29.74	27.59	11.5	0.01	288.63	0.92	1.67	0.52	58.66	134.08	93.84	83.70	2.95
2	23.3	39	257.0	1.4	786	0.64	49.47	34.97	28.61	10.2	0.01	288.45	0.92	1.72	0.52	61.83	130.89	91.63	91.27	3.21
3	23.1	32	257.0	1.8	784.8	0.64	49.47	27.81	28.26	8.8	0.01	288.26	0.92	1.71	0.52	64.75	127.97	89.58	96.64	3.40
4	22.9	36	257.0	2.1	784.7	0.64	49.47	23.79	27.92	9.7	0.01	288.38	0.92	1.69	0.52	62.57	130.15	91.11	92.89	3.27
5	21.8	53	257.0	2.5	785.7	0.64	49.47	19.46	26.12	13.2	0.01	288.87	0.92	1.59	0.52	54.71	138.01	96.61	71.46	2.52
6	21.8	47	257.0	1.8	785.8	0.64	49.47	26.84	26.12	11.3	0.01	288.60	0.92	1.59	0.52	58.34	134.38	94.06	78.96	2.78
7	22	37	257.0	1.5	784.8	0.64	49.47	33.55	26.44	9.3	0.01	288.33	0.92	1.61	0.52	62.68	130.04	91.03	86.84	3.08
8	22.3	33	257.0	1.6	784.2	0.64	49.47	31.11	26.90	8.1	0.01	288.18	0.92	1.63	0.52	65.68	127.05	88.93	93.41	3.29
9	22.1	29	257.0	2.2	785	0.64	49.47	22.50	26.60	7.3	0.01	288.05	0.92	1.62	0.52	67.43	125.29	87.70	97.55	3.43
10	22.2	42	257.0	1.7	785.3	0.64	49.47	29.74	26.76	10.9	0.01	288.55	0.92	1.63	0.52	59.47	133.25	93.28	82.75	2.91
11	22.6	36	257.0	2.1	784.5	0.64	49.47	23.99	27.42	9.6	0.01	288.37	0.92	1.66	0.52	62.53	130.19	91.13	91.24	3.21
12	22.3	28	257.0	1.9	784.4	0.64	49.47	26.11	26.90	7.1	0.01	288.02	0.92	1.63	0.52	68.12	124.60	87.22	98.50	3.47
13	22.2	26	257.0	1.7	785.2	0.64	49.47	28.57	26.76	6.5	0.01	287.94	0.92	1.63	0.52	69.57	123.15	86.20	99.38	3.50
14	22.4	33	257.0	1.7	785.9	0.64	49.47	28.64	27.09	8.7	0.01	288.24	0.92	1.64	0.52	64.37	128.35	89.85	92.39	3.25
15	23.4	41	257.0	2.1	785.3	0.64	49.47	24.04	28.78	10.8	0.01	288.54	0.92	1.73	0.52	60.65	132.07	92.45	91.90	3.23
16	23.6	37	257.0	2.8	785.3	0.64	49.47	17.62	29.13	10.1	0.01	288.44	0.92	1.75	0.52	62.29	130.43	91.30	97.78	3.44
17	24.4	39	257.0	2.3	785.4	0.64	49.47	21.90	30.56	11	0.01	288.56	0.91	1.83	0.52	61.05	131.67	92.17	98.67	3.47
18	23.6	29	257.0	2.0	785.8	0.64	49.47	24.55	29.13	8	0.01	288.15	0.92	1.75	0.52	67.08	125.64	87.95	103.96	3.66
19	23.3	36	257.0	2.4	785.7	0.64	49.47	20.83	28.61	9.5	0.01	288.35	0.92	1.72	0.52	63.35	129.37	90.56	97.19	3.42
20	23.5	31	257.0	2.3	785.3	0.64	49.47	21.37	28.96	9	0.01	288.29	0.92	1.74	0.52	64.64	128.08	89.65	100.45	3.54
21	22.7	32	257.0	2.2	786.2	0.64	49.47	22.63	27.59	8.7	0.01	288.24	0.92	1.67	0.52	64.63	128.09	89.66	95.83	3.37
22	21.8	34	257.0	1.4	786.8	0.64	49.47	35.08	26.12	8.9	0.01	288.27	0.92	1.59	0.52	63.40	129.32	90.53	86.83	3.08
23	21.1	31	257.0	1.5	786	0.64	49.47	32.24	25.02	7.8	0.01	288.12	0.93	1.53	0.52	65.32	127.40	89.18	87.21	3.07
24	21.5	40	257.0	2.1	785	0.64	49.47	23.79	25.64	10.2	0.01	288.45	0.92	1.57	0.52	60.34	132.38	92.67	81.68	2.88
25	22	51	257.0	2.0	784.4	0.64	49.47	24.40	26.44	12.5	0.01	288.77	0.92	1.61	0.52	56.17	136.55	95.58	75.67	2.66
26	22.2	43	257.0	3.1	784.5	0.64	49.47	16.00	26.76	10.8	0.01	288.54	0.92	1.63	0.52	58.67	133.05	93.13	84.94	2.99
27	23.5	34	257.0	2.8	785.2	0.64	49.47	17.70	28.96	8.9	0.01	288.27	0.92	1.74	0.52	64.87	127.85	89.49	102.12	3.59
28	23.2	41	257.0	2.5	785.5	0.64	49.47	19.56	28.44	10.7	0.01	288.52	0.92	1.71	0.52	60.69	132.03	92.42	91.87	3.23
29	24.2	39	257.0	1.8	784.7	0.64	49.47	27.94	30.20	10.5	0.01	288.49	0.91	1.81	0.52	61.94	130.78	91.55	97.52	3.43
30	24.1	30	257.0	1.7	784.3	0.64	49.47	29.14	30.02	8.1	0.01	288.16	0.92	1.80	0.52	67.29	125.43	87.80	105.17	3.70

jul								49.47	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	23.7	25	241.2	1.8	783.7	0.57	49.47	28.15	29.31	7.1	0.01	288.02	0.92	1.76	0.52	63.96	116.93	81.65	105.64	3.72
	2	23.2	29	241.2	1.6	783.7	0.57	49.47	31.53	28.44	7.3	0.01	288.05	0.92	1.71	0.52	63.06	117.83	82.48	100.55	3.54
	3	22.8	23	241.2	1.4	783.7	0.57	49.47	36.41	27.76	6.1	0.00	287.89	0.92	1.68	0.52	65.62	115.27	80.69	100.67	3.54
	4	22.8	30	241.2	3.1	784.3	0.57	49.47	16.14	27.76	7.8	0.01	288.12	0.92	1.68	0.52	61.58	119.30	83.51	101.77	3.58
	5	23.1	36	241.2	3.0	784.2	0.57	49.47	16.73	28.26	9.6	0.01	288.37	0.92	1.71	0.52	58.01	122.88	86.02	95.86	3.37
	6	22.2	42	241.2	2.4	784	0.57	49.47	20.25	26.76	10.8	0.01	288.54	0.92	1.63	0.52	54.98	125.91	88.14	83.55	2.94
	7	23.4	40	241.2	3.3	784.3	0.57	49.47	15.18	28.78	10.4	0.01	288.48	0.92	1.73	0.52	56.65	124.24	86.97	95.06	3.35
	8	23.7	42	241.2	2.7	784.6	0.57	49.47	18.32	29.31	10.7	0.01	288.52	0.92	1.76	0.52	56.29	124.59	87.21	95.03	3.35
	9	23.9	36	241.2	2.1	784	0.57	49.47	23.55	29.66	9.6	0.01	288.37	0.91	1.78	0.52	58.63	122.25	85.58	99.24	3.49
	10	24.5	34	241.2	2.5	783.1	0.57	49.47	19.90	30.75	9.5	0.01	288.36	0.91	1.83	0.52	59.32	121.57	85.10	105.26	3.71
	11	22.5	40	241.2	2.3	783.1	0.57	49.47	21.37	27.26	10.2	0.01	288.46	0.92	1.65	0.52	56.35	124.53	87.17	87.87	3.09
	12	22.6	43	241.2	2.5	784.2	0.57	49.47	19.56	27.42	11.2	0.01	288.59	0.92	1.66	0.52	54.53	126.36	88.45	84.75	2.98
	13	22.9	50	241.2	2.9	784.5	0.57	49.47	16.97	27.92	12.9	0.01	288.83	0.92	1.69	0.52	51.68	129.20	90.44	80.01	2.82
	14	23.2	47	241.2	2.4	783.7	0.57	49.47	20.72	28.44	12.8	0.01	288.82	0.92	1.71	0.52	52.07	128.82	90.17	82.14	2.89
	15	22.8	46	241.2	2.6	783.6	0.57	49.47	19.23	27.76	12.2	0.01	288.73	0.92	1.68	0.52	52.85	128.04	89.63	82.00	2.89
	16	21.3	45	241.2	2.2	783.9	0.57	49.47	22.81	25.33	11.3	0.01	288.61	0.92	1.55	0.52	53.39	127.50	89.25	75.14	2.64
	17	22.6	38	241.2	2.7	783.7	0.57	49.47	18.29	27.42	9.9	0.01	288.41	0.92	1.66	0.52	57.02	123.87	86.71	90.55	3.19
	18	22.8	40	241.2	2.8	783.7	0.57	49.47	17.86	27.76	10.8	0.01	288.54	0.92	1.68	0.52	55.43	125.46	87.82	88.21	3.11
	19	23.4	39	241.2	1.6	783.9	0.57	49.47	30.05	28.78	10.7	0.01	288.52	0.92	1.73	0.52	56.07	124.82	87.37	89.96	3.17
	20	24.5	38	241.2	1.5	784	0.57	49.47	33.16	30.75	10.9	0.01	288.55	0.91	1.83	0.52	56.52	124.37	87.06	95.55	3.36
	21	23	47	241.2	3.3	785	0.57	49.47	15.07	28.09	12.5	0.01	288.77	0.92	1.70	0.52	52.46	128.43	89.90	82.77	2.91
	22	23.3	44	241.2	2.8	785.7	0.57	49.47	17.89	28.61	11.7	0.01	288.66	0.92	1.72	0.52	54.11	126.77	88.74	87.97	3.10
	23	23.7	35	241.2	3.6	784.5	0.57	49.47	13.90	29.31	9.6	0.01	288.37	0.92	1.76	0.52	58.48	122.41	85.69	101.35	3.57
	24	22.4	43	241.2	2.8	783.3	0.57	49.47	17.46	27.09	10.8	0.01	288.54	0.92	1.64	0.52	55.13	125.76	88.03	85.45	3.01
	25	21.3	50	241.2	2.4	783.9	0.57	49.47	20.43	25.33	11.5	0.01	288.63	0.92	1.55	0.52	53.03	127.86	89.50	74.48	2.62
	26	22.8	41	241.2	3.1	784.1	0.57	49.47	16.07	27.76	10.5	0.01	288.50	0.92	1.68	0.52	56.00	124.89	87.42	89.94	3.17
	27	23.4	38	241.2	3.0	784.4	0.57	49.47	16.65	28.78	10.8	0.01	288.54	0.92	1.73	0.52	55.88	125.01	87.51	92.88	3.27
	28	23.3	41	241.2	1.7	784.6	0.57	49.47	28.71	28.61	10.7	0.01	288.52	0.92	1.72	0.52	55.99	124.89	87.43	89.63	3.16
	29	22.6	50	241.2	2.9	785.6	0.57	49.47	17.33	27.42	12.8	0.01	288.81	0.92	1.66	0.52	51.65	129.24	90.47	78.21	2.75
	30	21.9	51	241.2	2.9	785.2	0.57	49.47	17.10	26.28	12.4	0.01	288.76	0.92	1.60	0.52	51.86	129.03	90.32	74.96	2.64
	31	22.5	43	241.2	2.0	784.2	0.57	49.47	24.55	27.26	10.7	0.01	288.52	0.92	1.65	0.52	55.39	125.50	87.85	85.22	3.00
aug								49.47	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	23.6	36	240.4	1.6	783.6	0.58	49.47	31.53	29.13	9.4	0.01	288.34	0.92	1.75	0.52	59.52	120.76	84.53	95.34	3.36
	2	24.4	27	240.4	1.9	784.4	0.58	49.47	25.65	30.56	7.2	0.01	288.04	0.91	1.83	0.52	65.11	115.17	80.62	110.72	3.90
	3	25.2	23	240.4	2.8	783.9	0.58	49.47	17.70	32.06	7	0.01	288.01	0.91	1.90	0.52	66.30	113.98	79.79	121.72	4.28
	4	22.3	45	240.4	2.6	784.7	0.58	49.47	19.36	26.93	11.7	0.01	288.66	0.92	1.63	0.52	54.04	126.24	88.37	80.44	2.83
	5	22.8	45	240.4	2.8	784.2	0.58	49.47	17.98	27.76	11.7	0.01	288.66	0.92	1.68	0.52	54.41	125.87	88.11	84.20	2.96
	6	23.9	32	240.4	1.9	783.9	0.58	49.47	25.48	29.66	8.4	0.01	288.20	0.92	1.78	0.52	61.91	118.37	82.86	102.97	3.62
	7	24.2	25	240.4	2.6	783.9	0.58	49.47	18.77	30.20	7.4	0.01	288.07	0.91	1.81	0.52	64.46	115.82	81.06	112.10	3.95
	8	20.9	57	240.4	2.0	785.4	0.58	49.47	25.36	24.72	13.5	0.01	288.91	0.92	1.52	0.52	49.90	130.38	91.27	63.37	2.23
	9	19.2	69	240.4	3.0	786.4	0.58	49.47	16.73	22.25	14.7	0.01	289.07	0.93	1.38	0.52	46.83	133.45	93.41	46.04	1.62
	10	21.2	64	240.4	3.6	786.3	0.58	49.47	13.87	25.18	14.8	0.01	289.09	0.92	1.54	0.52	47.97	132.31	92.62	58.95	2.08
	11	23.3	55	240.4	2.0	785.5	0.58	49.47	25.09	28.61	14	0.01	288.98	0.92	1.72	0.52	50.69	129.59	90.71	77.42	2.73
	12	22.5	50	240.4	2.7	784.7	0.58	49.47	18.26	27.26	12.5	0.01	288.77	0.92	1.65	0.52	52.74	127.54	89.28	78.57	2.77
	13	21.9	53	240.4	2.6	784.4	0.58	49.47	19.33	26.28	12.7	0.01	288.80	0.92	1.60	0.52	51.96	128.32	89.82	73.40	2.58
	14	20.7	54	240.4	3.9	786	0.58	49.47	12.68	24.42	12.5	0.01	288.77	0.93	1.50	0.52	51.47	128.81	90.17	66.01	2.32
	15	21.9	48	240.4	2.4	786.7	0.58	49.47	20.43	26.28	12	0.01	288.70	0.92	1.60	0.52	53.20	127.08	88.95	76.28	2.69
	16	22.8	43	240.4	2.6	785.5	0.58	49.47	19.17	27.76	10.8	0.01	288.53	0.92	1.68	0.52	56.10	124.18	86.93	87.79	3.09
	17	22.7	37	240.4	1.9	785.2	0.58	49.47	25.65	27.59	9.5	0.01	288.36	0.92	1.67	0.52	58.60	121.68	85.18	90.84	3.20
	18	23.1	35	240.4	1.3	785.8	0.58	49.47	36.75	28.26	8.7	0.01	288.24	0.92	1.71	0.52	60.60	119.68	83.78	93.34	3.29
	19	23.5	28	240.4	1.6	786.2	0.58	49.47	30.86	28.96	7.8	0.01	288.12	0.92	1.74	0.52	62.93	117.35	82.15	100.63	3.54
	20	24	24	240.4	2.3	786	0.58	49.47	21.77	29.84	7.2	0.01	288.04	0.92	1.79	0.52	64.76	115.52	80.87	109.96	3.87
	21	24.1	24	240.4	1.4	785.4	0.58	49.47	36.41	30.02	6.9	0.01	288.00	0.92	1.80	0.52	65.57	114.71	80.30	105.19	3.70
	22	23.4	35	240.4	1.9	785.6	0.58	49.47	25.99	28.78	8.8	0.01	288.26	0.92	1.73	0.52	60.63	119.65	83.75	97.98	3.45
	23	23.2	31	240.4	2.7	785.7	0.58	49.47	18.09	28.44	8.3	0.01	288.19	0.92	1.71	0.52	61.55	118.73	83.11	101.53	3.57
	24	23.5	40	240.4	1.8	785.4	0.58	49.47	27.68	28.96	10.6	0.01	288.51	0.92	1.74	0.52	57.02	123.26	86.28	91.35	3.22
	25	22.5	49	240.4	2.7	784.1	0.58	49.47	18.00	27.26	12.7	0.01	288.80	0.92	1.65	0.52	52.38	127.90	89.53	77.74	2.74
	26	21.7	51	240.4	2.9	783.9	0.58	49.47	17.02	25.96	12	0.01	288.70	0.92	1.58	0.52	53.06	127.22	89.05	75.20	2.65
	27	20.6	54	240.4	2.6	784.2	0.58	49.47	18.77	24.27	11.7	0.01	288.66	0.92	1.49	0.52	52.81	127.47	89.23	68.91	2.43
	28	20.8	49	240.4	2.6	785.8	0.58	49.47	18.83	24.57	11.3	0.01	288.60	0.93	1.51	0.52	53.68	126.60	88.62	71.98	2.53
	29	22.9	44	240.4	1.9	784.4	0.58	49.47	25.65	27.92	11.6	0.01	288.65	0.92	1.69	0.52	54.66	125.62	87.93	83.99	2.96
	30	23.5	34	240.4	1.9	784.1	0.58	49.47	26.41	28.96	9.4	0.01	288.34	0.92	1.74	0.52	59.44	120.84	84.59	96.22	3.39
	31	24.4	[illegible]	240.4	1.9	784.9	0.58	49.47	26.21	30.56	8.4	0.01	288.30	0.91	1.83	0.52	62.33	117.95	82.56	105.99	3.73

sep								49.47	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	-14.94	ERR	0.00
	1	20.7	24	250.5	0.8	785.1	0.67	49.47	59.79	24.42	7.1	0.01	288.02	0.93	1.50	0.52	68.90	118.94	83.26	81.73	2.88
	2	20.7	26	250.5	1.7	784.4	0.67	49.47	28.28	24.42	6.8	0.01	287.96	0.93	1.50	0.52	69.68	118.17	82.72	88.47	3.11
	3	20.7	25	250.5	1.7	783.7	0.67	49.47	29.66	24.42	6.7	0.01	287.97	0.93	1.50	0.52	69.94	117.90	82.53	88.52	3.12
	4	20.7	38	250.5	2.5	784.2	0.67	49.47	19.90	24.42	10	0.01	288.43	0.92	1.50	0.52	62.13	125.71	88.00	77.01	2.71
	5	20.7	39	250.5	1.7	785.3	0.67	49.47	28.49	24.42	9.3	0.01	288.33	0.93	1.50	0.52	63.66	124.18	86.93	78.82	2.77
	6	20.7	22	250.5	2.0	785.9	0.67	49.47	24.87	24.42	6.6	0.01	287.95	0.93	1.50	0.52	70.20	117.64	82.35	90.13	3.17
	7	20.7	26	250.5	2.0	785.8	0.67	49.47	24.55	24.42	6.1	0.00	287.88	0.93	1.50	0.52	71.55	116.29	81.40	92.21	3.25
	8	20.7	26	250.5	1.9	785.1	0.67	49.47	25.70	24.42	6.6	0.01	287.95	0.93	1.50	0.52	70.20	117.64	82.35	89.90	3.16
	9	20.7	27	250.5	1.8	785.6	0.67	49.47	27.48	24.42	6.9	0.01	287.99	0.93	1.50	0.52	69.42	118.43	82.90	88.29	3.11
	10	20.7	30	250.5	1.7	786.3	0.67	49.47	29.36	24.42	7.1	0.01	288.02	0.93	1.50	0.52	68.90	118.94	83.26	87.08	3.07
	11	20.7	25	250.5	1.4	786.8	0.67	49.47	34.24	24.42	6.2	0.00	287.90	0.93	1.50	0.52	71.28	116.56	81.59	89.25	3.14
	12	20.7	29	250.5	1.6	786.3	0.67	49.47	30.45	24.42	7	0.01	288.01	0.93	1.50	0.52	69.16	118.68	83.08	87.22	3.07
	13	20.7	25	250.5	1.9	786	0.67	49.47	26.23	24.42	6.4	0.01	287.93	0.93	1.50	0.52	70.73	117.11	81.97	90.55	3.19
	14	20.7	23	250.5	1.5	785.9	0.67	49.47	33.84	24.42	5.6	0.00	287.81	0.93	1.50	0.52	72.96	114.88	80.42	91.48	3.22
	15	20.7	23	250.5	1.8	786.2	0.67	49.47	27.94	24.42	5.4	0.00	287.79	0.93	1.50	0.52	73.54	114.30	80.01	93.92	3.31
	16	20.7	23	250.5	1.6	786.3	0.67	49.47	30.61	24.42	5.5	0.00	287.80	0.93	1.50	0.52	73.25	114.59	80.22	92.75	3.26
	17	20.7	24	250.5	2.1	785.8	0.67	49.47	24.04	24.42	5.7	0.00	287.83	0.93	1.50	0.52	72.67	115.17	80.62	93.97	3.31
	18	20.7	30	250.5	2.4	785.1	0.67	49.47	20.32	24.42	8.5	0.01	288.22	0.93	1.50	0.52	65.49	122.35	85.65	83.34	2.93
	19	20.7	43	250.5	2.7	785.2	0.67	49.47	18.32	24.42	10.3	0.01	288.47	0.93	1.50	0.52	61.49	126.35	88.45	75.88	2.67
	20	20.7	36	250.5	2.2	785.7	0.67	49.47	22.72	24.42	8.4	0.01	288.20	0.93	1.50	0.52	65.72	122.12	85.48	83.31	2.93
	21	20.7	34	250.5	1.7	785.9	0.67	49.47	29.36	24.42	7.9	0.01	288.13	0.93	1.50	0.52	66.91	120.93	84.65	84.05	2.96
	22	20.7	31	250.5	1.9	785.7	0.67	49.47	25.47	24.42	6.9	0.01	287.99	0.93	1.50	0.52	69.42	118.43	82.90	88.78	3.12
	23	20.7	29	250.5	1.6	785.8	0.67	49.47	30.29	24.42	6.5	0.01	287.94	0.93	1.50	0.52	70.47	117.37	82.16	89.12	3.14
	24	20.7	33	250.5	2.1	786.3	0.67	49.47	23.27	24.42	7.5	0.01	288.08	0.93	1.50	0.52	67.89	119.95	83.96	86.89	3.06
	25	20.7	33	250.5	1.9	785.9	0.67	49.47	26.65	24.42	7.6	0.01	288.09	0.93	1.50	0.52	67.65	120.19	84.14	85.75	3.02
	26	20.7	31	250.5	2.4	785.9	0.67	49.47	21.02	24.42	7	0.01	288.01	0.93	1.50	0.52	69.16	118.68	83.08	89.52	3.15
	27	20.7	26	250.5	2.3	785.5	0.67	49.47	21.77	24.42	5.8	0.00	287.82	0.93	1.50	0.52	72.96	114.88	80.42	95.11	3.35
	28	20.7	27	250.5	1.5	785.2	0.67	49.47	32.69	24.42	5.9	0.00	287.86	0.93	1.50	0.52	72.11	115.73	81.01	90.71	3.19
	29	20.7	27	250.5	1.4	785	0.67	49.47	35.62	24.42	6.2	0.00	287.90	0.93	1.50	0.52	71.28	116.56	81.59	88.91	3.13
	30	20.7	34	250.5	1.8	786.4	0.67	49.47	27.67	24.42	8.2	0.01	288.17	0.93	1.50	0.52	66.19	121.65	85.15	83.21	2.93
oct								49.47	ERR	6.11		ERR	ERR	ERR	0.44	0.00	21.34	-21.34	14.94	ERR	0.00
	1	17.1	31	250.1	2.1	787.7	0.76	49.47	23.55	19.50	7.4	0.01	288.06	0.94	1.23	0.52	71.21	116.34	81.44	65.80	2.32
	2	17.1	28	250.1	1.4	787.4	0.76	49.47	35.62	19.50	5.8	0.00	287.84	0.94	1.23	0.52	75.65	111.90	78.33	71.03	2.50
	3	17.1	27	250.1	1.6	786.7	0.76	49.47	31.19	19.50	5.5	0.00	287.80	0.94	1.23	0.52	76.55	111.01	77.71	72.75	2.56
	4	17.1	31	250.1	2.5	787.6	0.76	49.47	19.73	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	69.65	2.45
	5	17.1	32	250.1	2.2	788.3	0.76	49.47	22.11	19.50	6.8	0.01	287.98	0.94	1.23	0.52	72.81	114.74	80.32	68.51	2.41
	6	17.1	34	250.1	1.8	788.2	0.76	49.47	27.68	19.50	6.8	0.01	287.98	0.94	1.23	0.52	72.81	114.74	80.32	67.97	2.39
	7	17.1	31	250.1	2.1	789.1	0.76	49.47	23.75	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	113.35	79.35	70.47	2.48
	8	17.1	32	250.1	1.3	788.1	0.76	49.47	37.59	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	67.86	2.39
	9	17.1	34	250.1	1.4	789.1	0.76	49.47	34.87	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	113.35	79.35	69.23	2.44
	10	17.1	33	250.1	2.1	789	0.76	49.47	23.65	19.50	7.1	0.01	288.02	0.94	1.23	0.52	72.00	115.55	80.88	67.07	2.36
	11	17.1	41	250.1	1.6	788.2	0.76	49.47	31.19	19.50	6.4	0.01	287.92	0.94	1.23	0.52	73.92	113.63	79.54	69.23	2.44
	12	17.1	37	250.1	1.4	788	0.76	49.47	35.18	19.50	7.4	0.01	288.06	0.94	1.23	0.52	71.21	116.34	81.44	65.05	2.29
	13	17.1	34	250.1	2.0	788.9	0.76	49.47	25.03	19.50	7.2	0.01	288.03	0.94	1.23	0.52	71.74	115.82	81.07	66.53	2.34
	14	17.1	32	250.1	1.5	788.6	0.76	49.47	32.79	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	68.29	2.40
	15	17.1	37	250.1	1.5	788.3	0.76	49.47	32.88	19.50	6.3	0.00	287.91	0.94	1.23	0.52	74.20	113.35	79.35	39.78	1.40
	16	17.1	37	250.1	1.6	788.7	0.76	49.47	30.53	19.50	7.1	0.01	288.02	0.94	1.23	0.52	72.00	115.55	80.88	37.81	1.33
	17	17.1	50	250.1	1.5	788.6	0.76	49.47	32.51	19.50	7	0.01	288.00	0.94	1.23	0.52	72.27	115.28	80.70	38.20	1.34
	18	17.1	68	250.1	1.1	788.6	0.76	49.47	45.98	19.50	10.3	0.01	288.46	0.94	1.23	0.52	64.26	123.30	86.31	32.50	1.14
	19	17.1	42	250.1	1.5	788.3	0.76	49.47	33.55	19.50	12.8	0.01	288.81	0.94	1.23	0.52	59.02	128.54	89.98	25.35	0.89
	20	17.1	42	250.1	1.5	788.3	0.76	49.47	33.84	19.50	7.7	0.01	288.10	0.94	1.23	0.52	70.43	117.12	81.98	36.76	1.29
	21	17.1	35	250.1	1.7	788.3	0.76	49.47	28.36	19.50	6.5	0.01	287.94	0.94	1.23	0.52	73.64	113.91	79.74	38.99	1.37
	22	17.1	38	250.1	2.0	788.8	0.76	49.47	24.19	19.50	7.8	0.01	288.11	0.94	1.23	0.52	70.18	117.37	82.16	35.59	1.25
	23	17.1	51	250.1	1.6	788.4	0.76	49.47	30.94	19.50	10.6	0.01	288.50	0.94	1.23	0.52	63.60	123.96	86.77	29.92	1.05
	24	17.1	57	250.1	1.9	787.8	0.76	49.47	26.11	19.50	11.2	0.01	288.59	0.94	1.23	0.52	62.30	125.25	87.68	27.83	0.98
	25	17.1	35	250.1	2.0	787.9	0.76	49.47	24.66	19.50	6.6	0.01	287.95	0.94	1.23	0.52	73.36	114.19	79.93	38.47	1.35
	26	17.1	34	250.1	2.0	788.1	0.76	49.47	24.61	19.50	6.2	0.00	287.90	0.94	1.23	0.52	74.49	113.07	79.15	39.40	1.39
	27	17.1	33	250.1	1.9	787.9	0.76	49.47	25.59	19.50	6.2	0.00	287.90	0.94	1.23	0.52	74.49	113.07	79.15	39.48	1.39
	28	17.1	37	250.1	1.6	788.1	0.76	49.47	31.79	19.50	7.6	0.01	288.09	0.94	1.23	0.52	70.69	116.86	81.80	36.80	1.30
	29	17.1	44	250.1	1.9	788.9	0.76	49.47	25.88	19.50	9.2	0.01	288.31	0.94	1.23	0.52	66.76	120.79	84.55	32.49	1.14
	30	17.1	46	250.1	1.2	789.4	0.76	49.47	40.78	19.50	9.1	0.01	288.29	0.94	1.23	0.52	67.00	120.56	84.39	34.42	1.21
	31	17.1	51	250.1	1.4	789.4	0.76	49.47	36.18	19.50	10.2	0.01	288.44	0.94	1.23	0.52	64.48	123.08	86.15	31.50	1.11

nov							49 47	ERR	6 11		ERR	ERR	ERR	0 44	0 00	21 34	-21 34	-14 94	ERR	0 00
1	14 6	40	244 5	2 5	789 1	0 88	49 47	19 96	16 62	7 9	0 01	288 13	0 95	1 07	0 52	75 57	107 83	75 48	26 91	0 95
2	14 6	37	244 5	1 5	789 3	0 88	49 47	32 23	16 62	6 6	0 01	287 95	0 95	1 07	0 52	79 29	104 12	72 88	31 06	1 09
3	14 6	35	244 5	1 4	788 9	0 88	49 47	36 06	16 62	6 1	0 00	287 88	0 95	1 07	0 52	80 81	102 59	71 81	32 47	1 14
4	14 6	36	244 5	1 2	788 3	0 88	49 47	39 93	16 62	5 9	0 00	287 85	0 95	1 07	0 52	81 44	101 97	71 38	33 15	1 17
5	14 6	32	244 5	1 7	787 9	0 88	49 47	29 36	16 62	5 1	0 00	287 74	0 95	1 07	0 52	84 06	99 34	69 54	34 35	1 21
6	14 6	39	244 5	2 0	787 5	0 88	49 47	24 92	16 62	6 6	0 01	287 95	0 95	1 07	0 52	79 29	104 12	72 88	30 54	1 07
7	14 6	50	244 5	1 7	788 2	0 88	49 47	28 85	16 62	8 8	0 01	288 25	0 95	1 07	0 52	73 18	110 23	77 16	25 68	0 90
8	14 6	49	244 5	1 8	788 3	0 88	49 47	27 94	16 62	8 5	0 01	288 21	0 95	1 07	0 52	73 96	109 44	76 61	26 29	0 93
9	14 6	38	244 5	1 4	787 8	0 88	49 47	34 97	16 62	7 5	0 01	288 07	0 95	1 07	0 52	76 68	106 72	74 71	29 27	1 03
10	14 6	40	244 5	1 7	787 4	0 88	49 47	29 90	16 62	6 9	0 01	287 99	0 95	1 07	0 52	78 40	105 01	73 50	30 22	1 06
11	14 6	36	244 5	1 6	787 8	0 88	49 47	30 61	16 62	5 8	0 00	287 84	0 95	1 07	0 52	81 76	101 65	71 15	32 81	1 15
12	14 6	30	244 5	1 4	787 7	0 88	49 47	34 65	16 62	6 3	0 00	287 91	0 95	1 07	0 52	80 20	103 21	72 25	31 94	1 12
13	14 6	31	244 5	1 4	786 7	0 88	49 47	34 97	16 62	4 9	0 00	287 72	0 95	1 07	0 52	84 76	98 65	69 06	35 08	1 23
14	14 6	36	244 5	1 5	786 7	0 88	49 47	32 23	16 62	5 8	0 00	287 84	0 95	1 07	0 52	81 76	101 65	71 15	32 92	1 16
15	14 6	42	244 5	1 5	787 1	0 88	49 47	33 26	16 62	6 6	0 01	287 98	0 95	1 07	0 52	78 69	104 71	73 30	30 71	1 08
16	14 6	43	244 5	1 4	786 8	0 88	49 47	34 65	16 62	7 1	0 01	288 02	0 95	1 07	0 52	77 82	105 59	73 91	30 15	1 06
17	14 6	42	244 5	2 1	787 4	0 88	49 47	23 84	16 62	7	0 01	288 01	0 95	1 07	0 52	78 11	105 30	73 71	29 49	1 04
18	14 6	40	244 5	1 9	788 3	0 88	49 47	26 71	16 62	6 1	0 00	287 88	0 95	1 07	0 52	80 81	102 59	71 81	31 86	1 12
19	14 6	40	244 5	1 6	788 6	0 88	49 47	31 27	16 62	6 2	0 00	287 89	0 95	1 07	0 52	80 50	102 90	72 03	31 93	1 12
20	14 6	42	244 5	1 4	788 6	0 88	49 47	36 06	16 62	6 3	0 00	287 91	0 95	1 07	0 52	80 20	103 21	72 25	32 03	1 13
21	14 6	42	244 5	1 6	788 7	0 88	49 47	31 02	16 62	5 7	0 00	287 83	0 95	1 07	0 52	82 06	101 33	70 93	33 06	1 16
22	14 6	34	244 5	1 6	787 9	0 88	49 47	30 77	16 62	4 6	0 00	287 67	0 95	1 07	0 52	85 81	97 60	68 32	35 56	1 26
23	14 6	33	244 5	1 6	787	0 88	49 47	31 19	16 62	4 5	0 00	287 66	0 95	1 07	0 52	86 17	97 24	68 07	35 81	1 26
24	14 6	34	244 5	1 8	787 7	0 88	49 47	27 41	16 62	5	0 00	287 73	0 95	1 07	0 52	84 41	99 00	69 30	34 48	1 21
25	14 6	37	244 5	1 6	788 3	0 88	49 47	31 70	16 62	5 8	0 00	287 84	0 95	1 07	0 52	81 76	101 65	71 15	32 88	1 16
26	14 6	39	244 5	1 7	788 8	0 88	49 47	29 29	16 62	5 8	0 00	287 84	0 95	1 07	0 52	81 76	101 65	71 15	32 73	1 15
27	14 6	36	244 5	2 0	788 3	0 88	49 47	25 25	16 62	5 4	0 00	287 78	0 95	1 07	0 52	83 06	100 35	70 24	33 42	1 18
28	14 6	33	244 5	1 5	788 2	0 88	49 47	32 05	16 62	4 8	0 00	287 70	0 95	1 07	0 52	85 10	98 31	68 81	36 17	1 24
29	14 6	32	244 5	2 0	788 7	0 88	49 47	24 92	16 62	4 2	0 00	287 62	0 95	1 07	0 52	87 28	96 13	67 29	36 26	1 28
30	14 6	37	244 5	1 6	789 2	0 88	49 47	30 53	16 62	4 7	0 00	287 69	0 95	1 07	0 52	85 45	97 95	68 57	36 32	1 24
dec							49 47	ERR	6 11		ERR	ERR	ERR	0 44	0 00	21 34	21 34	14 94	ERR	0 00
1	12 1	49	223 9	1 9	788 8	0 85	49 47	26 23	14 12	6 2	0 00	287 89	0 96	0 93	0 52	75 68	92 28	64 58	24 51	0 86
2	12 7	38	223 9	1 6	787 9	0 85	49 47	31 70	14 69	4 8	0 00	287 70	0 96	0 96	0 52	80 66	87 28	61 08	29 59	1 04
3	13 2	34	223 9	1 3	787 4	0 85	49 47	37 71	15 17	4 3	0 00	287 63	0 96	0 99	0 52	82 98	84 97	59 48	32 12	1 13
4	13	31	223 9	1 7	787 5	0 85	49 47	29 59	14 98	4 1	0 00	287 61	0 96	0 98	0 52	83 45	84 49	59 14	31 68	1 12
5	14	28	223 9	1 7	786 7	0 85	49 47	29 82	15 99	4	0 00	287 59	0 95	1 04	0 52	84 99	82 95	58 07	34 60	1 22
6	14 1	33	223 9	1 1	788 3	0 85	49 47	43 88	16 09	4 5	0 00	287 66	0 95	1 04	0 52	83 30	84 63	59 24	34 01	1 20
7	13 7	29	223 9	1 7	789 2	0 85	49 47	29 59	15 68	4 2	0 00	287 62	0 96	1 02	0 52	83 90	84 03	58 82	33 37	1 17
8	14 3	30	223 9	1 6	788 6	0 85	49 47	31 79	16 30	4 3	0 00	287 63	0 95	1 05	0 52	84 24	83 69	58 58	34 70	1 22
9	13 7	34	223 9	1 8	789 2	0 85	49 47	27 88	15 68	5 1	0 00	287 74	0 96	1 02	0 52	80 81	87 12	60 99	31 21	1 10
10	12 1	34	223 9	1 1	789	0 85	49 47	45 26	14 12	4 6	0 00	287 67	0 96	0 93	0 52	80 67	87 27	61 09	29 14	1 03
11	12	40	223 9	1 7	788 3	0 85	49 47	29 44	14 03	5 2	0 00	287 76	0 96	0 92	0 52	78 60	89 34	62 54	26 87	0 95
12	10	44	223 9	1 8	787 6	0 85	49 47	26 96	12 28	5 1	0 00	287 74	0 97	0 82	0 52	76 73	91 21	63 85	22 45	0 79
13	12	37	223 9	1 3	786 6	0 85	49 47	37 84	14 03	4 4	0 00	287 65	0 96	0 92	0 52	81 24	86 70	60 69	29 10	1 02
14	13 4	34	223 9	1 4	787 6	0 85	49 47	35 29	15 37	5 1	0 00	287 74	0 95	1 00	0 52	80 48	87 46	61 22	30 74	1 08
15	14 2	34	223 9	1 8	788 4	0 85	49 47	28 15	16 19	5 3	0 00	287 77	0 95	1 05	0 52	80 73	87 21	61 05	32 04	1 13
16	13 2	39	223 9	1 7	788 7	0 85	49 47	29 00	15 17	5 6	0 00	287 81	0 96	0 99	0 52	78 67	89 27	62 49	28 82	1 01
17	12 7	43	223 9	1 8	789 8	0 85	49 47	27 74	14 69	6 3	0 00	287 91	0 96	0 96	0 52	76 03	91 91	64 34	25 83	0 91
18	12 1	49	223 9	1 9	790 7	0 85	49 47	26 53	14 12	6 6	0 01	287 95	0 96	0 93	0 52	74 54	93 40	65 38	23 55	0 83
19	10 6	43	223 9	1 7	789 8	0 85	49 47	29 37	12 78	5 2	0 00	287 76	0 97	0 85	0 52	77 07	90 87	63 61	23 66	0 83
20	10 6	37	223 9	1 5	788 2	0 85	49 47	33 65	12 78	4 4	0 00	287 65	0 97	0 85	0 52	79 65	88 28	61 80	25 80	0 91
21	12 5	40	223 9	1 3	787 4	0 85	49 47	38 99	14 49	5 7	0 00	287 83	0 96	0 95	0 52	77 59	90 34	63 24	27 38	0 96
22	14 5	38	223 9	2 3	788 1	0 85	49 47	21 25	16 51	6	0 00	287 87	0 95	1 07	0 52	78 86	89 07	62 35	30 87	1 09
23	15 5	40	223 9	1 6	788 3	0 85	49 47	30 53	17 61	6 8	0 01	287 98	0 95	1 13	0 52	77 57	90 37	63 26	32 18	1 13
24	16	45	223 9	1 6	788 1	0 85	49 47	31 19	18 18	7 8	0 01	288 12	0 95	1 16	0 52	75 28	92 66	64 86	31 32	1 10
25	15 5	47	223 9	2 0	788 6	0 85	49 47	24 19	17 61	7 9	0 01	288 13	0 95	1 13	0 52	74 49	93 44	65 41	29 21	1 03
26	14 8	55	223 9	2 0	791 3	0 85	49 47	25 09	16 84	9	0 01	288 28	0 95	1 08	0 52	70 93	97 00	67 90	24 65	0 87
27	13	58	223 9	1 9	790 9	0 85	49 47	26 65	14 98	8 3	0 01	288 18	0 96	0 98	0 52	70 92	97 02	67 91	21 66	0 76
28	13 3	46	223 9	1 8	788 6	0 85	49 47	27 61	15 27	6 2	0 00	287 89	0 96	0 99	0 52	76 96	90 98	63 68	27 57	0 97
29	12 2	38	223 9	1 2	788 8	0 85	49 47	41 81	14 21	4 8	0 00	287 70	0 96	0 93	0 52	80 11	87 82	61 48	28 61	1 01
30	11 4	27	223 9	1 6	789 8	0 85	49 47	31 36	13 48	3 2	0 00	287 48	0 96	0 89	0 52	84 97	82 96	58 07	28 61	1 07
31	11 1	32	223 9	2 3	790 2	0 85	49 47	21 77	13 21	3 7	0 00	287 55	0 97	0 88	0 52	82 70	85 24	59 67	28 13	0 99

A.IV Evapotranspiration

IV.1 Background

In studying the water budget of an area, neither the reference nor the potential evapotranspiration provide sufficient information on the actual water output from a catchment by evaporation and transpiration. In semi-arid regions, since a significant part of precipitation or irrigation water evaporates back into the atmosphere, E is very important for the determination of the available groundwater in these areas.

Evapotranspiration is composed of evaporation and transpiration. The first is basically a physical process, which transforms a liquid medium into vapour phase. When this transfer occurs through plants and is influenced by physiological (biological, biochemical and biophysical) processes as well, it is called transpiration. The term potential evapotranspiration refer to the maximum rate of evapotranspiration from a large area covered completely and uniformly by actively growing vegetation with adequate moisture at all times. (note : The area is specified as large to avoid the possible effects of local advection).

The development of evapotranspiration is basically determined by the availability of water to be transformed into vapour and by the energy needed to change the phase of a given amount of liquid. The former is more important to determine the actual evapotranspiration from terrain, whereas the latter from free water surface. This also implies that in humid climate the limiting factor for evaporation may be the available energy, whereas evapotranspiration is probably limited by the available water in arid regions.

Many formulae are proposed in the literature to calculate the expected value of evapotranspiration. Most of them are based on consideration of available energy by taking into account the radiation, the temperature, the deficit of moisture saturation of the air and the wind velocity. The most frequently applied formulae were given by Penman (1948) and by Thornthwaite, (Thornthwaite and Holzman, 1939).

Penman (1948) derived a formula which is based on the empirical Dalton equation and the energy balance approach. For open water (saturated surface)it can be written as;

$$Eo = \frac{ss\ Rn + v\ Ea}{ss + v} \qquad (1)$$

Where

Eo 'open water evaporation' (kg/m2/s)

Rn is net radiation flux of a hypothetical water surface (W/m^2)

ss slope of saturation water vapour temperature curve at Ta (mbar/k)

v psychrometric constant mbar/k

Ea is a drying power of the air or aerodynamic 'resistance' and equal to [Ea = f(u)(es-e)], f(u)is a function of the wind speed, being defined as f(u)=3.7 + 4 u2, and u2 average wind speed at 2 m height (m/s).

Thornthwaite equation (vapour flux method) can be written as;

$$Eo = \frac{.622\ K^2\ pa\ (u2-u1)(e1-e2)}{P(\ln z2/z1)^2} \qquad (2a)$$

Where

k is the von Karman constant.

pa is the air density

u1,e1 wind velocity and vapour pressure measured at elevation z1

u2,e2 wind velocity and vapour pressure measured at elevation z2, respectively.

.622 is constant so as vapour pressure can be substituted for the specific humidity (qv =.622 e/P), and P the air pressure(the same at both heights).

Here evaporation as can be seen from the equation calculated using air measurements at two fairly close levels above the water surface and considers the turbulent transfer of water vapour through the small height difference. Although this is called the friction turbulent method, it is applied only for uniform conditions, and convection turbulence should be included when the ground surface get hot ((i.e because the use of air temperature instead of surface temperature because the difference is always small except in case of lake or saline land where the difference get larger)). Since measurements are made usually at only one height in a standard climate station, the above equation is simplified by assuming that the wind velocity u1 =0 at the roughness height z1=zo and that the air is saturated with moisture there. At height z2, the vapour pressure is ea, P is the air pressure, and the vapour pressure at the surface is taken to be es, the saturated vapour pressure corresponding to the air temperature, so equation (2a) becomes;

$$Eo = \frac{.622\ K^2\ pa\ u2(es-ea)}{P(\ln z2/zo)^2} \qquad (2b)$$

the variables as defined above.

The evaluation of actual water loss from a vegetated land surface by evaporation plus transpiration adds further complexities to the processes involved in the evaporation from an open water surface. Old-Penman formula (1948) refer to evapotranspiration of a well defined type of surface, similar to that of Thornthwaite, they give only information on the reference and potential evapotranspiration, by describing the possible upper limit of evapotranspiration from a given area but not the actual value. Penman (1948) introduced empirical method for the estimation of evapotranspiration from a well watered short grass cover, being a version of the *crop factor approach.* (In order to simply compute the maximum possible evapotranspiration of a certain crop, Etp, it is often related empirically to the evaporation of a hypothetical shallow water surface, often called 'open water evaporation, Eo. This quantity has thus no strict physical meaning because it describes for the prevailing weather conditions the evaporation of a water surface that does not exist! Etp is related to Eo simply through a crop factor, according to

$$Etp = f \cdot Eo \tag{3}$$

with Eo being calculated by the above equations (1 and 2b). The crop coefficient f expresses the factors determined by the evaporating surface. It varies depending upon the type of the crop and the stage of its growth.

To estimate actual evapotranspiration from meteorological data, several investigators (e.g. Brutsaert, 1982, De Bruin, 1988, Shaw, 1990, and Lemeur and Zhang, 1990) agreed that, Penman-Monteith model successfully describes the transpiration and interception loss from different kind of vegetation, such as tall, rough forest, arable crops heathland and grassland. However, a crucial parameter in the equation is the canopy resistance rc, which was evaluated from the measured evapotranspiration for three crops from water budget methods, then substituted in the Penman-Monteith equation.

IV.2 Penman-Monteith Model

An adjustment has been suggested to Penman's approach, which combines the bulk aerodynamic equation for the vertical transfer of sensible heat and water vapour and the surface energy-balance equation with bulk stomatal resistance. This is because, even when it is well supplied with water near the soil surface or at the roots, evaporating vegetation cannot, in general, be considered wet, except after rainfall or dew formation. Thus the specific humidity at the surface of the foliage element is likely to be somewhat smaller than the saturation value at the corresponding temperature, and equations such as Penman's are no longer applicable. In other word, the bulk transfer equation will not be valid because the specific humidity at the leaf surface is unknown i.e. can not be assumed as if it has been saturated as Penman assumed when he calculated Δ. To remedy this, various resistance parameters have been introduced (e.g Penman 1956, Monteith, 1965) to characterize the transfer between the supposedly vapour-saturated stomatal cavities and the atmosphere. The main drawback of this resistance (rc) to be applied to estimate the actual evapotranspiration from a meteorological data is that it is generally unknown. Moreover a recent study in an arid zone (Lemeur and

Zhang, 1990) has indicated the crucial role of the rc value in the estimated actual evapotranspiration. Although the transpiration mechanism is well understood i.e the regulation of the passage of water through the plant cavities, it is difficult to quantify or present in mathematical form, In other words, the interactions of such factors as the distribution of heating by radiation and the distribution of vapour sources on different parts of the canopy through the day and through the season, the current state of biological activity and senescence, the moisture stress at the roots, the specific physiological characteristics of the species under consideration, are quite intricate and difficult to quantify. This explains why, until now, despite the attempts reported in the literature (for example, Van Bavel, 1967, Szeucz and Long, 1969, Garratt, 1978b), there are no general relationships for rc in terms of some other easily measurable soil, plant or atmospheric parameters. In Monteith's concept the vegetation layer is described in a very simple way, i.e, the canopy is treated as if it were one 'big leaf' and a canopy resistance rc is assigned. This 'big leaf' has the same albedo and surface roughness as the actual crop.

The actual evapotranspiration rate in Penman-Monteith model is given by

$$\lambda E = \frac{\Delta\,(Rn-G) + \rho a Cp/ra(es - ea)}{\Delta + \gamma(1+rc/ra)} \tag{4}$$

Where

E rate of Evapotranspiration ($kg/m^2/s$)

Δ rate of change of saturated vapour pressure with temperature (mb/ C)

Rn the net radiation (W/m2)

G soil heat flux density (W/m2)

ρa air density (Kg/m^3)

Cp specific heat of air at constant pressure (1005 J/Kg)

es saturated vapour pressure at screen temperature (mb)

ea screen vapour pressure (mb)

γ psychromatic constant

λ latent heat of vaporization (= 2465 KJ/Kg)

rc canopy or surface resistance s/m

ra aerodynamic resistance s/m,

Parameterization of various variables of the above equation is discussed under two terms which contribute to the evapotranspiration in the Penman-Monteith model; the aerodynamic term and the energy term.

IV.2.1 Parameterization of the aerodynamic Term

In the original Penman equation this term is equivalent to the aerodynamic evapotranspiration (Ea),

$$Ea = f(u)\ (es - ea) \tag{5}$$

where f(u) is the wind function and it is defined as;

$$f(u) = .35 + .54\ u \tag{6}$$

where u is mean wind velocity at 2 m height in m/sec. Thom and Oliver (1977) noticed that the roughness length implied by this equation in the Penman aerodynamic term is approximately 1.4 mm which would be only approximate for very smooth surfaces e.g. very short grass (i.e it would underestimate the aerodynamic term for the vast majority of applications, as for regional application it would be at least a few centimetres and for forest few metres). So for a surface with large roughness this equation may not be valid. Moreover, although many forms of winds function are available, each is adapted to the particular conditions for which it was developed. So the aerodynamic resistance ra, introduced into the model to relate the wind function to the surface conditions.

The aerodynamic resistance, ra, defined as the resistance to the transport of water vapour from the evaporating surface into the atmosphere, and may for a specific surface (roughness) be written as a function of the wind,

$$ra = \frac{[\ln (z-d/zo)]^2}{k^2 u} \qquad (7)$$

Where

k, is von Karman constant and experimentally is found to be invariant and its commonly used value is of the order of 0.4.

zo, is the surface roughness length for rough surfaces (L) and its value is a function of the nature of the surface, that is the geometry, size and the arrangement of the roughnesses

z, is the height above the ground (L),

{reference level, height of net radiometers and it should be > 'h' mean height of trees, to satisfy the minimum fetch requirements (Pasquill(1972)}

d, is the zero-plane displacement height (L) was introduced to allow for a shift in reference level (z=0, or where u=zero) which should be located somewhere between the tops and the bases of the roughness obstacle (see e.g. Thom 1975), (upper part of canopy).

{ln because of the semi-log description of wind profile, the term (z-d/zo)is dimensionless height above z=d, (z=h the canopy top and z=d is the upper part of canopy}

With the present state of knowledge, there is still no good substitute for the experimental determination of zo and d from wind velocity profile measurements. However, in the absence of such measurements makes it necessary for these parameters to be estimated from simple geometric characteristics of the surface. In this connection many studies have been conducted to relate zo with measurable characteristics of the surface (Brutsaert, 1982). The most obvious and also the simplest available surface characteristic, is the mean height of the roughness obstacles, ho. Brutsaert(1982) showed that several recent works, have confirmed that, Paeschke ratio (ho/zo) has a constant value of 7.5 for various grassy surfaces. Moreover, the Paeschke's ratio (ho/zo) is relatively insensitive to the method adopted to calculate it. Similar to (ho/zo), several studies; Rutter et al (1975) Thom et al (1975) and Brutsaert (1982), showed that, ratio (d/ho)= .7 (values; .75, .76,and .67) appear to be fairly representative for natural crop covered surface. However, it is clear that the ratio cannot really be constant, because, for extremely sparsely placed roughness elements, the ground surface is the true reference and d should be close to zero, similarly, for very densely placed obstacles, d/ho should approach unity. Fortunately the exact value of d as appear in (z-d) is not as critical as zo, provided that z>>zo.

Consequently, d was estimated using the Paeschke's ratio;

$$d = .70 * ho \qquad (8)$$

and zo was estimated using the ratio;

$$zo = ho/7.5 \qquad (9)$$

However these values were verified by tabulated values of zo for various surfaces as determined in different sites and by various investigators (Table 1).

Typical values of z, ho, d and zo used in the calculation of the actual evapotranspiration in Sana'a basin for each crop are given in Table 1b. using values for each crop is important because using a gross average of roughness length for the whole basin, may be inappropriate as the effects of the short grass might be neglected by the dominating effects of tall grass.

Table 1 Approximate values of the roughness height of natural surfaces,(compiled from Chow et al, 1988)

surface	Roughness height zo mm
water	.1 - 0.6
Grass (up to 10 cm high)	1.1 - 20.0
Grass (10-50 cm high)	20.0 - 50.0
Vegetation (1-2m high)	200
Trees (10-15m high)	400.0 - 700.0

Table 1b Typical values for ho, d, Z and Zo, in (L) used in the calculation of the actual evapotranspiration for different crops.

Surface condition	ho	d	Z	Zo
irrigated soil"apples"	8	5	100	1
irrigated grapes	450	300	1500	60
irrigated qat	750	500	2000	90

Using daily measured wind in m/s, the daily aerodynamic resistance for each crop were calculated.

The required parameters for the moist air were calculated from the well known relations as follows;

the air density (ρa) is calculated from the ideal gas law

$$\rho a = P/Ra\ T \qquad (10)$$

where
P is barometric pressure (mb),
T is the absolute temperature and Ra is the gas constant for moist air (J/Kg.K) and calculated from it is relation with the dry air constant, as

$$Ra = Rd\ (\ 1 + .608\ q\ ) = 287.04\ (1 + .608\ q\ )\ \ J/kg.k$$

Where Rd is the gas constant for day air and equal 287 J/Kg.K, q is the specific humidity, which is approximated by

$$q = 0.622\ ea\ P\ \ kg\ water/kg\ moist\ air$$

0.622 is the ratio of molecular weight of water vapour 18.016 to the average molecular weight of dry air (28.966).

saturation vapour pressure es, is the maximum moisture content the air can hold for a given air temperature. At this vapour pressure, the rates of evaporation and condensation are equal. Over a water surface the saturation vapour pressure is related to the air temperature by the following approximate equation:

$$es = 6.11\ \ \exp\ (17.27\ T/237.3+T) \qquad (11)$$

where es in mbar and T is in degrees celsius.

By differentiating equation (11) the gradient $\Delta = des/dT$ (Clausius-Clapeyron equation) of the saturated vapour pressure curve is found by

$$\Delta = es/T\ (6790/T - 5.028) \qquad (12)$$

where T is the absolute temperature, and the origin of these constant come from equation proposed by Richards(1971), and compared well with Clausius-Clapeyron equation.

ea actual vapour pressure of the air , at a given temperature, has been calculated from the relative humidity (RH) through the relation (2.15), where data is not available;

$$ea = es * RH/100 \quad \text{mbar} \qquad (13)$$

The Psychometric (γ) constant is equal to

$$\gamma = Cp\ Kh\ P\ /\ .622\ L\ Kw \qquad (14)$$

where the ratio Kh/Kw of the heat and vapour diffusivities is commonly taken to be unity (Priestley and Taylor, 1972), and P is barometric pressure in mbar L is the latent heat of vaporization and Cp is the air specific heat (=1005). By substituting the suitable values, equation (14) becomes;

$$\gamma = 6.5 * 10^{4} * P \qquad (\text{mbar K}) \qquad (15)$$

The latent heat of vaporization varies slightly with temperature according to

$$L = 2.501 * 10^6 - 2370\ T \quad (J/kg) \tag{16}$$

where T is temperature in degree celsius.

2.3.3.2 Parameterization of the Energy Term

The energy budget equation for the earth's surface may be written as (Brutseart, 1982);

$$Q = LE + H \tag{17}$$

where Q is the available energy flux density, LE is the energy required for evaporation and H is loss of sensible heat. In hydrology practice and at the land surface it is sufficiently accurate to define the available energy Q as the net radiation (Rn) minus soil heat flux density (G).
so the energy budget equation may simply written as;

$$Rn - G = LE + H \tag{18}$$

Direct measurements of the net radiation are not available and hence it was broken into its components;

$$Rn = Rs\ (1 - \alpha) + Rl \tag{19}$$

where Rs is (global) short wave radiation, α is albedo of the surface and Rl is the net long wave radiation.

Then these components, if not measured as well, can be obtained by theoretical methods or simpler empirical formulae, the basis are given below;

Global short-wave radiation; Rs, is the radiant flux resulting directly from the solar radiation. As it passes through the atmosphere, the solar radiation is modified by scattering, absorption and reflection by different type of molecules and colloidal particles; thus at the earth's surface the global radiation consists of direct solar radiation and diffuse sky radiation. Data for the short-wave radiation measured at Sana'a airport and Al-Irra weather stations are available. Previous studies in Sana'a Basin, and for the years without records, has been calculated it from the following formula;

$$Rs = (A + B\ n\ N)Ra \qquad (20)$$

Where Ra is the extraterrestrial radiation, n is the measured actual sunshine hours and N maximum possible sunshine hours.
A and B are radiation constants taken to be .25 and .50 respectively, following the standard values used in the FAO methodology. Based on research done by Williams(1980) for the Montane Plains and Wadi Rima Project, different values of .33 and .44 were proposed for the constant to the highland area. By using the recorded data for sunshine (airport station)and radiation from Al-Irra, a constant similar to that suggested by FAO has been obtained.

The surface Albedo, α, is the ratio of the global short wave reflected radiative flux and the flux of the corresponding incident radiation; in contrast to the term reflectivity the albedo also includes the diffuse portion of the radiation. Its value depend upon the altitude of the sun and the cloudiness, and an equation proposed by Anderson (1954) for surface lakes ;

$$\alpha = a\ S^{b} \qquad (21)$$

where S is sun's altitude in degrees and a ,b are constants having value of 1.18 and .77, respectively. Similar relations for other surfaces have been developed, and typical values used at the present study are given in Table 2

Table 2 Albedo or reflection coefficients, (fraction)

Surface	albedo
Qat	0.25
grapes	0.25
Bare soil	0.20

The long-wave radiation is the radiant flux resulting from the emission of the atmospheric gases and earth surface. Although good instruments are becoming available, it is still not as easy to measure long wave radiation in nature as global radiation (Brutsaert, 1982). Therefore in practice, it is still expeditious to calculate it on the basis of measurements of more easily-measured variables. No measurements available in Sana'a basin for the net long-wave radiation and it is obtained as a function of absolute temperature, actual vapour pressure and sunshine ratio. For convenience, the net long-wave radiation is considered through its two components, namely; the downward radiation from atmosphere, Rld, and the upward radiation from the surface, Rlu.

The upward component was obtained by ;

$$Rlu = \varepsilon \sigma Ts^4 \tag{22}$$

Where Ts is the absolute temperature of the surface, ε its emissivity (.95-1),and σ is Stefan-Boltzman constant (= $4.86*10^{3}$ J/d/m2/k). As in many practical situation, ε is taken as unity, and furthermore since Ts is rarely known, especially over land, the air temperature Ta was used instead of Ts.

The downward long wave component under clear sky is obtained from;

$$Rldc = \varepsilon_a \sigma Ta^4 \tag{23}$$

Where ε_a is the atmospheric emissivity under clear sky. Several expression have been published for ε_a. Most of these are strictly empirical, but it is also possible to derive it on physical grounds. The derivation of the latter is quite complex and require in general vertical profile data of humidity and temperature. Such data are rarely available where the long wave radiation is needed; as a result, simpler methods have been developed. One of the better-known empirical equations in the literature (van Wijk and Ubing, 1963, Brutsaert 1982 , based on correlations with measurements is due to Brunt 1932 , namely

$$\varepsilon_a = a + b\ ea \tag{24}$$

where a and b are constant determined from observational data. With ea in mb .34 and .044, respectively were used by Rhebergen & van Waveren (1990) for the Yemen Highlands. Although it was not mentioned the origin of these constants, similar values were used in the present study. All the constants reported in the available literature were derived from different latitude, although for similar altitude, a value of 0.6 has been reported by Anderson (1954). It is interesting to mention that, the values of a and b do not varies between different locations only, but also at the same location and for time intervals of the order of one week. The variability of these constants have been revealed by studies at Lake Henfer, (Anderson, 1954). Some values are given in Table 3.

Table 3 Values of the constants a and b (mbar$^{-1/2}$) in Brunt's formula.
(compiled from van Wijk and Ubing, 1963)

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In contrast to Rlu, Rld is further affected by the cloudiness. One of several adjustment to the equation of the net long-wave radiation, which have been proposed in the literature to include the effect of cloudiness is

$$Rnl = Rnl' \ (1 - a' \ m^{b'}) \qquad (25)$$

Where m is the fractional cloud cover of the sky and a' and b' are constants, and Rnl' (= ε_a Rld - Rlu) is the net long wave radiation under clear sky. However when data on cloud cover are not available, it can be adequate as an approximation to substitute n/N in the above equation for m (Brutsaert, 1982). Actually this implicit in an equation used by Penman (1948).

$$Rnl = Rnl'[\ a' + (1-a')(n/N)] \qquad (26)$$

where a' is a constant which he took to be 0.1 . Other studies have yielded estimate of 0.3 Fitzpatrick and Stern (1965) and .23 as reported by Brutsaert (1982) from work done by Impens, so that a =.2 may be taken as an average value for practical calculations. Although Rhebergen & van Waveren (1990) used a =0.1 for the Yemen Highlands, in the present study 0.2 was used.

Relative sunshine (n/N), where n is the actual number of hours of bright sunshine and N are number of daylight hours, and for a given latitude and month it can be read from tables. Daily observed actual sunshine from Sana'a airport was used. For missing data, average mean monthly data has been used. The *maximum possible* sunshine hours for Sana'a is given in Table 4

Table 4 Mean daily duration of maximum possible sunshine hours(N)at Latitude 15 .75' N

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
11.3	11.6	12.0	12.6	12.9	13.1	13.0	12.7	12.2	11.8	11.4	11.2

The net long wave radiation (W/m^2)was calculated in the present study from the following equation;

$$Rnl = \sigma/86400 * T^4 *(.34 -.044\ ea^{1\ 2}\ (.2 + .8n\ N) \qquad (27)$$

It is worth bearing in mind always the fact that not only with respect to the present study but generally when evapotranspiration is to be estimated from the energy budget and related methods, the calculation of the net radiation, which is not often measured directly on climatological station. The existing semi-empirical expression to determine the net radiation need a lot of input data and contain several empirical constants. The values of these constants are still uncertain.

The last parameter in Penman-Monteith equation to be evaluated was the heat flux into the Ground, (G). Although several methods are available, all methods need a lot of data that is not available, this may be because the physical processes related to soil evaporation and soil heat flux appear to be very complicated and are not yet fully understood (De Bruin, 1988). The more visible one in the present case is the temperature gradient method which in principle, can be calculated from measurements of soil temperature gradient, provided the thermal conductivity of the soil is known. However, the gradient obtained from differences involves often a large error and it is not easy to determine thermal conductivity Brutsaert (1982). Therefore, this method is not usually suitable for direct calculation of the heat flux at the surface, but only to determine the heat flux at some larger depth where the moisture content and the temperature gradients do not vary as drastically van Wijk and Ubing (1963). As the necessary measurements were not available, the surface soil heat flux was estimated on the basis of empirical relationships. The simplest assumption here is that the surface flux G is proportional to the net radiation;

$$G = C\ Rn \qquad (28)$$

where C is an empirical constant. For a bare soil Fuchs and Hada (1972) found that 0.3 represents an average value approximately. Other studies of cultivated surface gave other values for the constant of the proportionality, which may vary according to moisture content of the soil and the amount of net radiation. Inspection shows that, combining all their data, one would obtain a C value of approximately 0.4 (Brutsaert, 1982). In the light of these different studies it seems that C with .3 may be used as a good compromise value for bare soils, or when Rn is taken at the soil surface. However, for surfaces covered by vegetation, Rn taken at the top of the canopy C is likely to be considerably smaller, so that it is often negligible (Brutsaert, 1982). In the present study and considering that the crops do not cover the ground completely which implies that evaporation from the soil is taking place as well, a value of 0.3 has been used.

Appendix B

(B-1 TO B-12)

Irrigation recharge data

For each site, the followings are given;

-Calibration of Neutron probe, and the regression analysis
-Neutron probe readings
-Measured soil volumetric moisture content
-Measured soil matric potential
-SOIL output

APPLE AI RAWDHA SITE

Calibration of Neutron probe

Counts ration	Moisture content
8798	0.258
9030	0.28
8330	0.206
8854	0.26
9003	0.28
9250	0.32
9061	0.28
9190	0.295
8636	0.241
8570	0.234
8540	0.23
8964	0.273
8950	0.27

Regression Output:

Constant		-0.7071
Std Err of Y Est		0.005076
R Squared		0.974188
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	0.00011	
Std Err of Coef.	5.38E-06	

Moisture= .00011*C -0.7071

Site Crop Soil 4ir

al-Rawdha, Apples

Neutron probe Counts

Depth "cm	25-May	10-Jun	17-Jun	27-Jun	07-Jul	19-Jul	29-Jul	11-Aug	25-Aug
25	9061	9003	8798	8250	9408	9290	10243	9518	8765
50	9190	9185	9030	8930	9427	9336	9508	9394	9001
75	8638	8422	8330	8359	9033	8775	9073	9047	8701
100	9044	9065	8854	8789	9382	9073	9062	9241	9128
125	8570	8964	8743	8673	9177	8940	8825	9001	8956
150	8971	8950	8700	8661	9083	9057	8791	9032	9000

Measured Volumetric moisture content

25	0.290	0.283	0.261	0.200	0.328	0.315	0.420	0.340	0.257
50	0.304	0.303	0.286	0.275	0.330	0.320	0.339	0.326	0.283
75	0.243	0.219	0.209	0.212	0.287	0.258	0.291	0.288	0.250
100	0.288	0.290	0.267	0.260	0.325	0.291	0.290	0.309	0.297
125	0.236	0.279	0.255	0.247	0.302	0.276	0.264	0.283	0.278
150	0.280	0.277	0.250	0.246	0.292	0.289	0.260	0.286	0.283

Measured Matric potential cm

Depth									
25	260								
50		180	300	430	160	190		165	375
100		290	330			265		205	260
125	620				220				
150				550				285	295

GRAPES SAWAN SITE SOIL 5ir

NEUTRON PROBE CALIBRATION

count ratio	*moist.cc/cc*
8366	0.26
8336	0.281
8556	0.294
8612	0.274
8759	0.285
9445	0.341
9852	0.366
9819	0.37
9373	0.33

Regression Output:		
Constant		-0.28146
Std Err of Y Est		0.010086
R Squared		0.947651
No. of Observations		9
Degrees of Freedom		7
X Coefficient(s)	6.58E-05	
Std Err of Coef.	5.84E-06	

MOISTURE = 6.58E-5 * CR - .28146

Depth	23-May	07-Jun	20-Jun	06-Jul	18-Jul	29-Jul	10-Aug	21-Aug
Neutron Probe Counts								
25	8324	8366	9073	8312	7770	7870	9162	7862
50	8557	8336	9852	8993	7905	8397	9299	8488
75	8830	8556	9819	9330	8309	8766	9051	8659
100	8855	8612	9373	9332	8410	8571	8861	8544
125	8901	8759	9239	9373	8760	9446	9187	9084
150	9571	9445	9726	9753	9175	10010	9810	9621
Measured Volumetric moisture content								
25	0.266	0.269	0.316	0.265	0.230	0.236	0.321	0.236
50	0.282	0.267	0.367	0.310	0.239	0.271	0.330	0.277
75	0.300	0.282	0.365	0.332	0.265	0.295	0.314	0.288
100	0.301	0.285	0.335	0.333	0.272	0.283	0.302	0.281
125	0.304	0.295	0.326	0.335	0.295	0.340	0.323	0.316
150	0.348	0.340	0.359	0.360	0.322	0.377	0.364	0.352

Measured Matric Potential, cm

Depth	23-May	07-Jun	20-Jun	06-Jul	18-Jul	29-Jul	10-Aug	21-Aug
25					365	235		
50		285	160	230			180	275
75					230	250		
100		235	190	180		310	225	165
125					250		190	200
150				130				

QAT BAYT ALOZARI SOIL 6ir

Calibration of the neutron probe

6356	0.167
7404	0.172
8698	0.212
6623	0.184
7741	0.201
8194	0.198
9059	0.241
9781	0.31
9772	0.336

Regression Output:

Constant		-0.12438
Std Err of Y Est		0.029402
R Squared		0.792255
No. of Observations		9
Degrees of Freedom		7
X Coefficient(s)	4.27E-05	
Std Err of Coef.	8.26E-06	

MC = 4.27e-5* CR -.12438

Depth	20-May	06-Jun	16-Jun	26-Jun	06-Jul	17-Jul	28-Jul	25-Aug
Neutron Probe Counts								
-25	8800	6449	6365	9442	8140	6957	6565	7830
-50	9805	8533	7404	10037	9179	7905	7462	8533
-75	10266	9236	8027	10263	9612	8673	8389	8767
-100	10388	9353	8698	10487	10072	9449	9078	8908
-125	10695	10032	9501	10449	10344	9840	9225	9165
-150	11787	10243	9747	10104	9906	9627	9401	9376
Measured Volumetric Moisture Content cc/cc								
25	0.251	0.151	0.147	0.279	0.223	0.173	0.156	0.210
50	0.294	0.240	0.192	0.304	0.268	0.213	0.194	0.240
75	0.314	0.270	0.218	0.314	0.286	0.246	0.234	0.250
100	0.319	0.275	0.247	0.323	0.306	0.279	0.263	0.256
125	0.332	0.304	0.281	0.322	0.317	0.296	0.270	0.267
150	0.379	0.313	0.292	0.307	0.299	0.287	0.277	0.276
Measured Matric Potential		cm						
depth								
25								
50	155	310		130	250	600	390	
100	110	150		100	130	220	250	
150				130	145	170	200	

The irrigated area and
The trends of cropping pattern
1972 TO 1993

	sorghum	wheat	barely	maize	tomato	potatoes	alfalfa	grapes	gat	other trees	TOTAL
1972	793	294	822	294	294	59	176	59	147	0	2937
1973	758	333	856	315	373	121	207	112	234	8	3317
1974	723	372	890	336	453	182	238	165	322	17	3698
1975	688	411	924	357	533	244	269	218	409	25	4078
1976	653	449	957	378	612	306	300	271	496	33	4458
1977	618	488	991	400	692	368	332	325	584	42	4838
1978	582	527	1025	421	772	430	363	378	671	50	5219
1979	547	566	1058	442	852	492	394	431	758	58	5599
1980	512	605	1092	463	931	554	425	484	846	67	5979
1981	477	644	1126	484	1011	615	456	537	933	75	6359
1982	442	683	1160	506	1091	677	487	591	1020	83	6740
1983	407	722	1193	527	1170	739	518	644	1108	92	7120
1984	372	761	1227	548	1250	801	549	697	1195	100	7500
1985	519	729	1143	520	1336	933	659	1150	1954	161	9104
1986	666	698	1058	491	1421	1065	770	1604	2712	222	10708
1987	814	666	974	463	1507	1197	880	2057	3471	283	12312
1988	961	635	890	434	1592	1329	991	2510	4229	344	13916
1989	1108	603	806	406	1678	1461	1101	2964	4988	406	15519
1990	1255	571	721	377	1763	1593	1211	3417	5746	467	17123
1991	1413	525	625	324	1824	1711	1312	3862	6495	527	18617
1992	1570	478	528	270	1884	1828	1412	4308	7244	588	20111
1993	1728	432	432	216	1945	1945	1512	4753	7993	649	21605

Water use m3/ha	3200	4550	3900	4550	4500	4500	14500	8000	7000	8000	6270	
Applied groundwater for irrigation												Total Abstractio
1972	2537568	1336335	3207204	1336335	1321650	264330	2555190	469920	1027950	0		14056482
1973	2425304	1513520	3338712	1432757	1680263	542677.5	3005633	895426.6	1639371	66666.66		16540329
1974	2313040	1690704	3470220	1529179	2038875	821025	3456075	1320933	2250792	133333.3		19024177
1975	2200776	1867889	3601728	1625601	2397488	1099373	3906518	1746440	2862212	200000		21508024
1976	2088512	2045073	3733236	1722023	2756100	1377720	4356960	2171947	3473633	266666.7		23991871
1977	1976248	2222258	3864744	1818445	3114713	1656068	4807403	2597453	4085054	333333.3		26475719
1978	1863984	2399443	3996252	1914868	3473325	1934415	5257845	3022960	4696475	400000		28959566
1979	1751720	2576627	4127760	2011290	3831938	2212763	5708288	3448466	5307896	466666.6		31443413
1980	1639456	2753812	4259268	2107712	4190550	2491110	6158730	3873973	5919316	533333.3		33927261
1981	1527192	2930996	4390776	2204134	4549163	2769458	6609173	4299480	6530737	600000		36411108
1982	1414928	3108181	4522284	2300556	4907775	3047805	7059615	4724986	7142158	666666.6		38894955
1983	1302664	3285366	4653792	2396978	5266388	3326153	7510058	5150493	7753579	733333.3		41378803
1984	1190400	3462550	4785300	2493400	5625000	3604500	7960500	5576000	8365000	800000		43862650
1985	1661511	3318720	4456617	2363978	6010000	4198750	9561139	9202666	13674889	1288889		55737158
1986	2132622	3174889	4127933	2234555	6395000	4793000	11161778	12829332	18984778	1777778		67611666
1987	2603733	3031059	3799250	2105133	6780000	5387249	12762417	16455999	24294667	2266667		79486174
1988	3074844	2887228	3470566	1975710	7165000	5981499	14363056	20082665	29604557	2755555		91360681
1989	3545955	2743398	3141883	1846288	7550000	6575749	15963695	23709332	34914446	3244444		1.03E+08
1990	4017066	2599567	2813200	1716866	7935000	7169999	17564331	27335984	40224334	3733333		1.15E+08
1991	4521243	2388245	2437067	1472177	8207500	7697499	19017553	30898648	45466556	4219556		1.26E+08
1992	5025421	2176922	2060933	1227488	8480000	8224999	20470775	34461312	50708778	4705778		1.38E+08
1993	5529600	1965600	1684800	982800	8752500	8752500	21924000	38024000	55951000	5192000		1.49E+08

The Return flow, For all without data, Return average used was 34%

								23%	29.3%	51%	
1972	862773.1	454353.9	1090449	454353.9	449361	89872.2	868764.6	108081.6	298105.5	0	4676115
1973	824603.4	514596.7	1135162	487137.4	571289.3	184510.4	1021915	205948.1	475417.5	34000	5454580
1974	786433.6	574839.4	1179875	519920.9	693217.5	279148.5	1175066	303814.7	652729.6	68000	6233044
1975	748263.8	635082.2	1224588	552704.4	815145.8	373786.7	1328216	401681.2	830041.6	102000	7011509
1976	710094.1	695325	1269300	585488	937074	468424.8	1481366	499547.7	1007354	136000	7789974
1977	671924.3	755567.7	1314013	618271.5	1059002	563063	1634517	597414.2	1184666	170000	8568438
1978	633754.6	815810.5	1358726	651055	1180931	657701.1	1787667	695280.8	1361978	204000	9346903
1979	595584.8	876053.2	1403438	683838.5	1302859	752339.3	1940818	793147.3	1539290	238000	10125368
1980	557415	936296	1448151	716622	1424787	846977.4	2093968	891013.8	1716602	272000	10903832
1981	519245.3	996538.8	1492864	749405.5	1546715	941615.6	2247119	988880.3	1893914	306000	11682297
1982	481075.5	1056782	1537577	782189	1668644	1036254	2400269	1086747	2071226	340000	12460762
1983	442905.8	1117024	1582289	814972.5	1790572	1130892	2553420	1184613	2248538	374000	13239226
1984	404736	1177267	1627002	847756.1	1912500	1225530	2706570	1282480	2425850	408000	14017691
1985	564913.8	1128365	1515250	803752.4	2043400	1427575	3250787	2116613	3965718	657333.3	17473707
1986	725091.5	1079462	1403497	759748.8	2174300	1629620	3795005	2950746	5505586	906666.6	20929723
1987	885269.3	1030560	1291745	715745.1	2305200	1831665	4339222	3784880	7045454	1156000	24385739
1988	1045447	981657.6	1179993	671741.5	2436100	2033710	4883439	4619013	8585321	1405333	27841755
1989	1205625	932755.2	1068240	627737.9	2567000	2235755	5427656	5453146	10125189	1654667	31297771
1990	1365802	883852.7	956488	583734.5	2697900	2437800	5971873	6287276	11665057	1904000	34753783
1991	1537223	812003.2	828602.7	500540.2	2790550	2617150	6465968	7106689	13185301	2151973	37996000
1992	1708643	740153.6	700717.3	417345.9	2883200	2796500	6960064	7926102	14705546	2399947	41238218
1993	1880064	668304	572832	334152	2975850	2975850	7454160	8745520	16225790	2647920	44480442
											32865429

ESTIMATION OF IRRIGATION RETURN
FROM WATER BALANCE 1986-1993

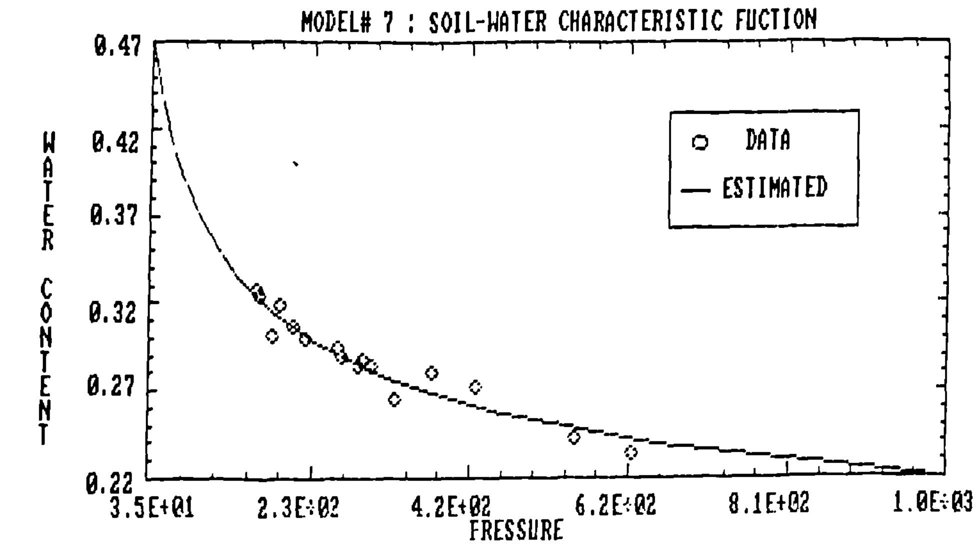
evapotranspiration	qat	grape	apple	Total applied water Rain	700 qat	800 grape	800 apple
1986	768	878.6	616.3	348.3	1048.3	1148.3	1148.3
1987	762.6	877.5	624.9	229.5	929.5	1029.5	1029.5
1988	819	931.7	666.6	219.2	919.2	1019.2	1019.2
1989	763.4	872.7	624.9	207.2	907.15	1007.15	1007.15
1990	821.4	937	645.1	225.6	925.6	1025.6	1025.6
1991	806.7	880.9	655.9	155.4	855.4	955.4	955.4
1992	739	850	612.1	334.8	1034.8	1134.8	1134.8
1993	772	878.4	628.7	269.2	969.2	1069.2	1069.2
				248.6438	948.6438	1048.644	1048.644

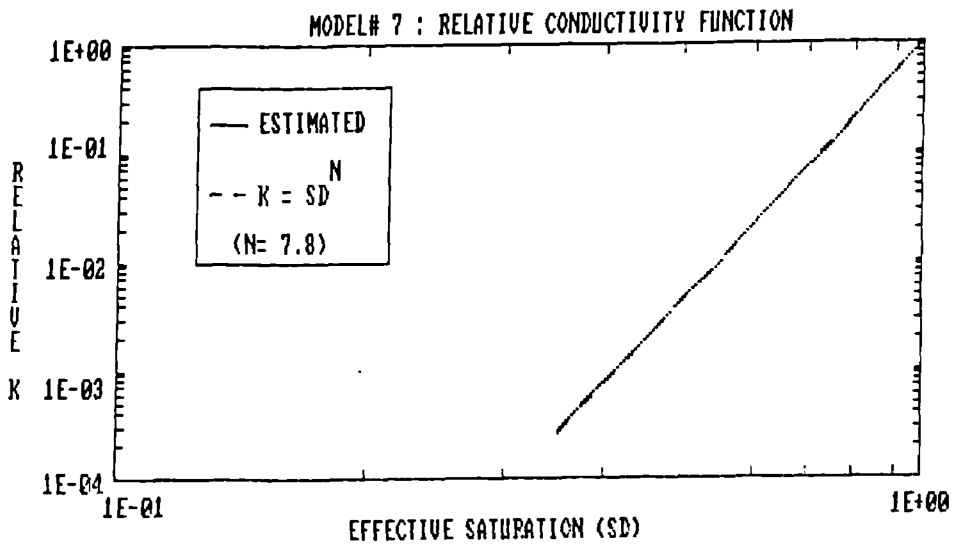
The Return (applied water - evaporation)				The percentage of the return			Average
1986	280.3	269.7	532	26.74	23.49	46.33	32.18
1987	166.9	152	404.6	17.96	14 76	39.30	24.01
1988	100.2	87.5	352.6	10.90	8.59	34.60	18.03
1989	143.75	134.45	382.25	15.85	13 35	37.95	22.38
1990	104.2	88.6	380 5	11 26	8.64	37.10	19.00
1991	48.7	74 5	299.5	5.69	7 80	31.35	14.95
1992	295.8	284.8	522.7	28 59	25 10	46.06	33.25
1993	197 2	190.8	440.5	20.35	17.85	41.20	26.46
				17.16553	14 94559	39 23597	23 78236

The cultivated area and The trends of cropping pattern 1986-1993	1986	1987	1988	1989	1990	1991	1992	1993
sorghum	666	814	961	1108	1255	1413	1570	1728
wheat	698	666	635	603	571	525	478	432
bare y	1058	974	890	806	721	625	528	432
maize	491	463	434	406	377	324	270	216
tomato	1421	1507	1592	1678	1763	1824	1884	1945
potatoes	1065	1197	1329	1461	1593	1711	1828	1945
a fa fa	770	880	991	1101	1211	1312	1412	1512
grapes	1604	2057	2510	2964	3417	3862	4308	4753
gat	2712	3471	4229	4988	5746	6495	7244	7993
other trees	222	283	344	406	467	527	588	649
T tal	10708	12312	13916	15519	17123	18617	20111	21605

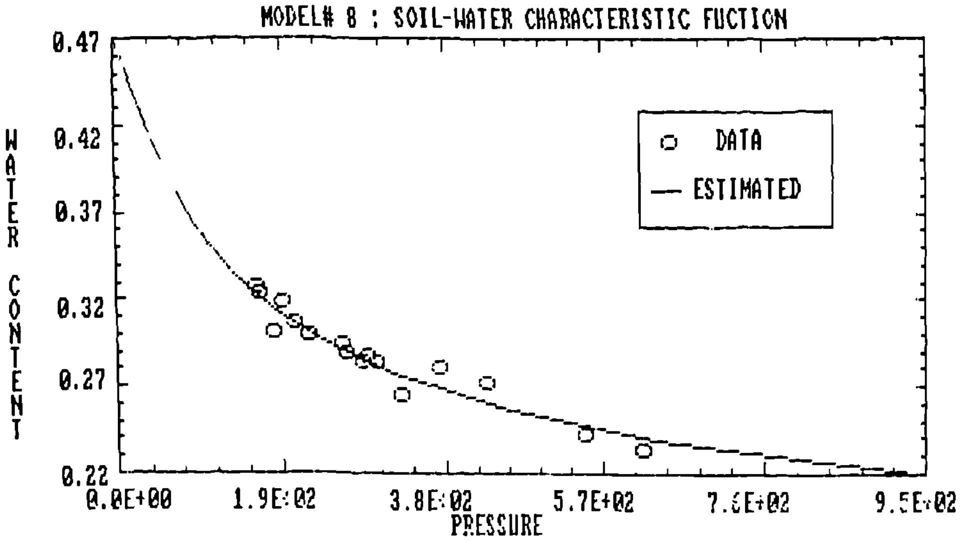
The effective rain		348.3	229.5	219.2	207.2	225.6	155.4	334.8	269.2	248.6438	
TOTAL APPLIED WATER											
	irrigation	1986	1987	1988	1989	1990	1991	1992	1993		
sorghum	320	4453848	4471098	5181112	5841961	6849097	6716872	10283267	10181375		6747329
wheat	455	5605249	4559911	4278174	3992699	3888495	3203922	3778755	3128544		4054469
barely	390	7814495	6034962	5421203	4811109	4440528	3408144	3830165	2847744		4826044
maize	455	3945095	3166952	2927525	2687059	2568130	1974982	2130703	1564272		2620590
tomato	450	11344730	10237800	10655151	11026356	11913080	11041824	14789120	13988440		11874563
potatoes	450	8502781	8134746	8895154	9603516	10764559	10355702	14344399	13988440		10573662
alfalfa	1450	13842914	14782400	16534354	18244852	20297099	21055710	25197407	25994304		19493630
grapes	800	18414903	21176814	25585316	29850049	35044731	36900710	48883371	50819076		33334371
gat	700	28431061	32259848	38875012	45249122	53188062	55560132	74962063	77468156		50749182
other trees	800	2551778	2916917	3510578	4084755	4786133	5039204	6675146	6939108		4562952
		1.05E+08	1.08E+08	1.22E+08	1.35E+08	1.54E+08	1.55E+08	2.05E+08	2.07E+08		1.49E+08
	average return	32.18	24.01	18.03	22.38	19.00	14.95	33.25	26.46		
sorghum		1433248	1077535	934155	1307431	1301328	1004172	3419186	2693992		13171047
wheat		1803769	1098939	771355	893566	738814	478986	1256436	827813		7869678
barely		2514704	1454426	977443	1076726	843700	509518	1273530	753513		9403560
maize		1269532	763236	527833	601364	487945	295260	708459	413906		5067533
tomato		3650734	2467310	1921124	2467698	2263485	1650753	4917382	3701341		23039828
potatoes		2736195	1960474	1603796	2149267	2045266	1548178	4769513	3701341		20514029
alfalfa		4454650	3562558	2981144	4083198	3856449	3147829	8378138	6878093		37342058
grapes		4327502	3112992	2200337	3999907	3013847	2878255	12269726	9045796		40848361
gat		7591093	5806773	4276251	7194610	6010251	3166927	21439150	15803504		71288560
other trees		1181473	1146348	1214660	1548122	1775656	1582310	3077242	2858912		14384724
Total return m3		30962901	22450589	17408097	25321889	22336741	16262188	61508762	46678211		30366172

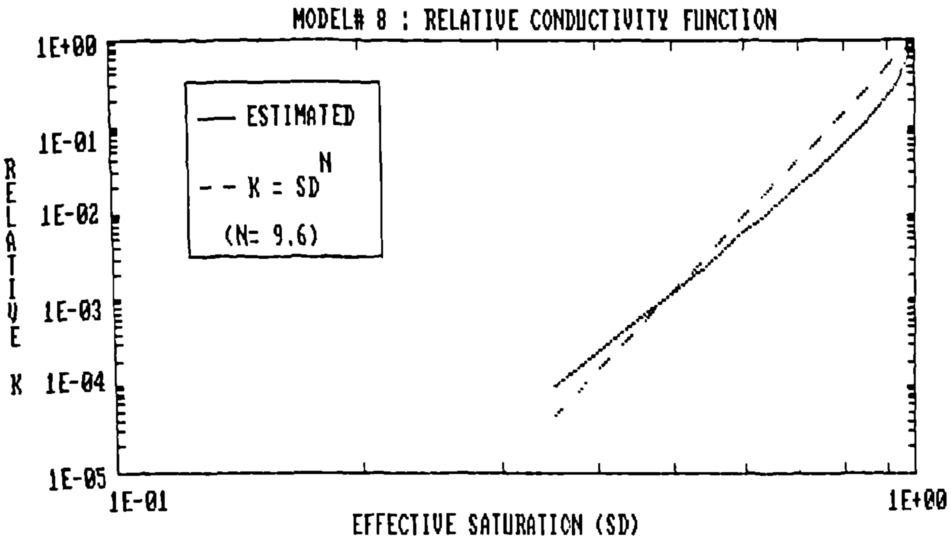
(soil 4ir) Brooks and Corey model



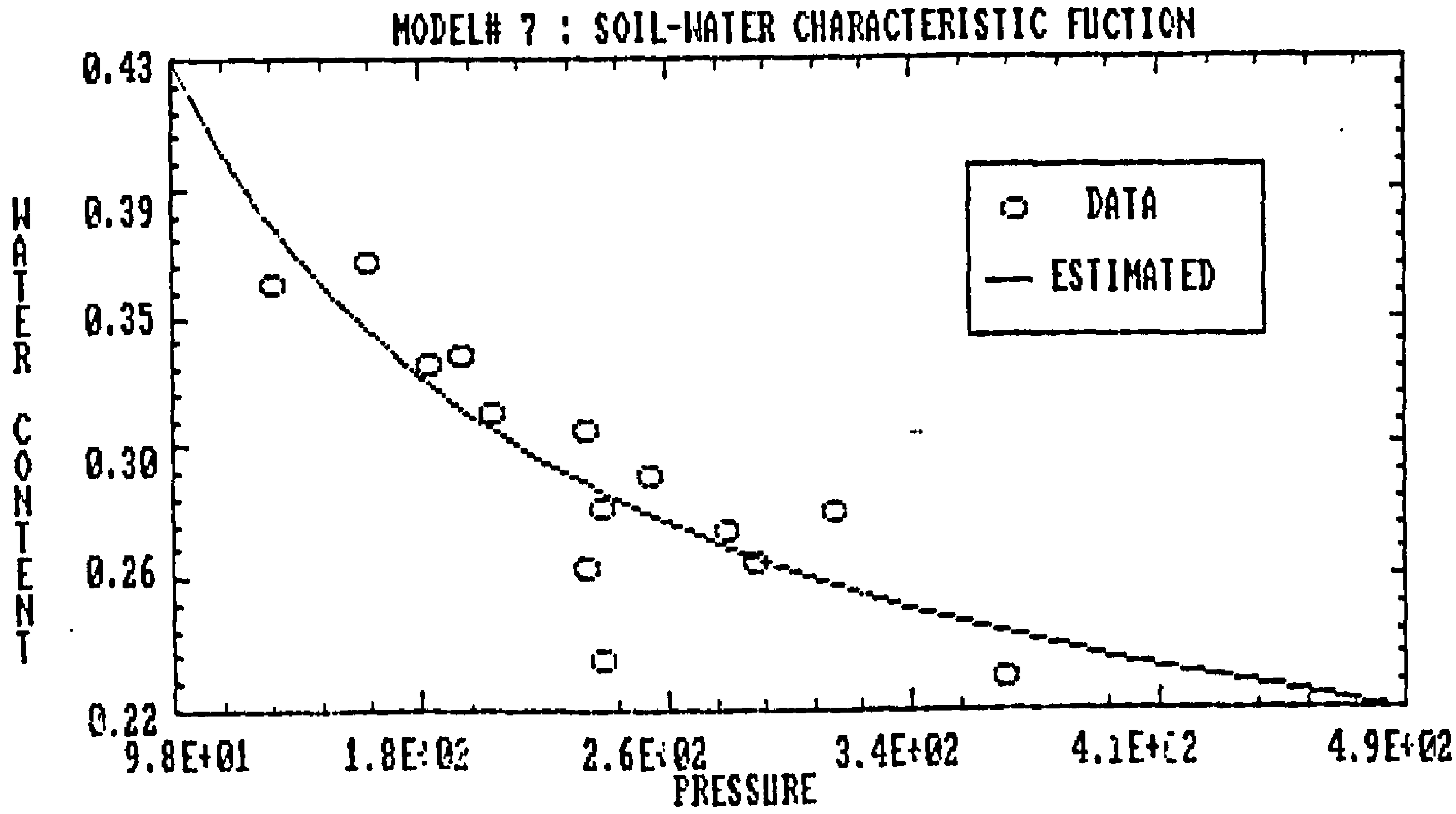


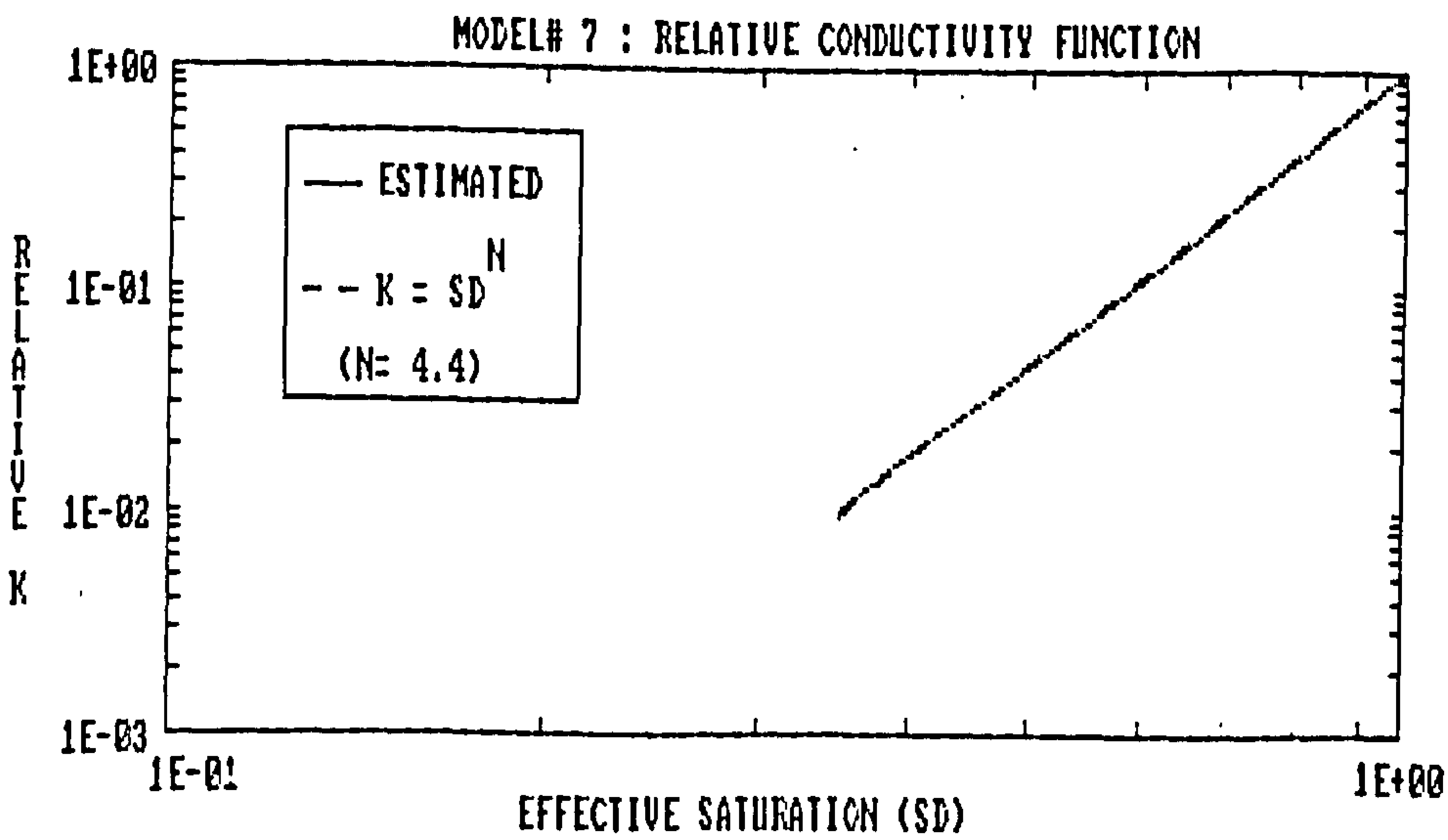
soil 4ir Van Genuchten



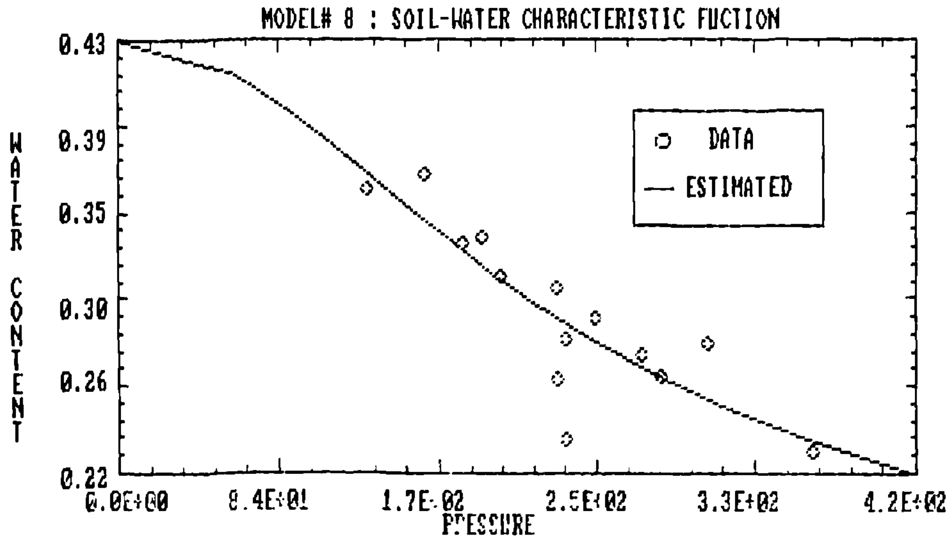


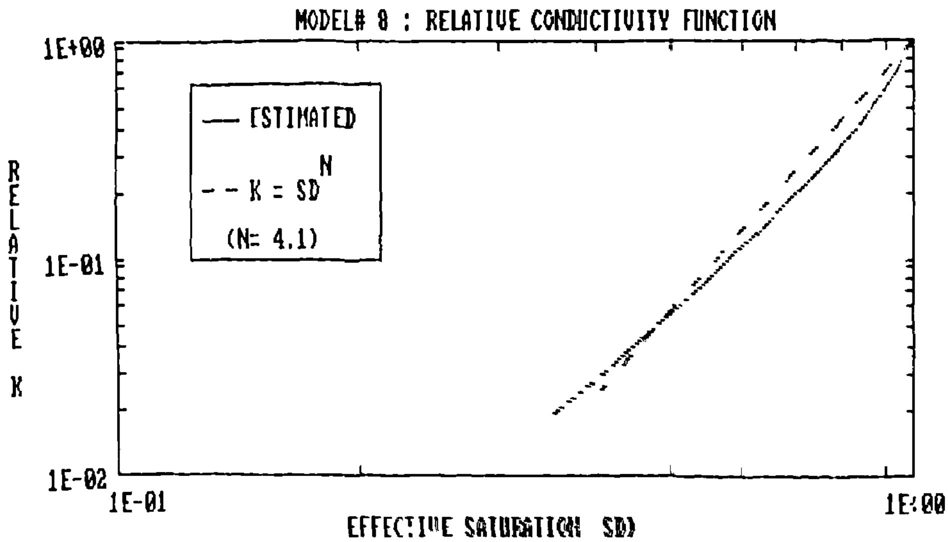
soil 5ir Brooks and Corey





soil 5ir Van Genuchten,





Appendix C

(C1 TO C23)

Wadi flow data

I

Summary of Floods peak discharge at three Wadis

Date	Wadi Q m^3/sec	alSyla base time (hr)	Wadi Q m^3/sec	Rawna base time (hr)	Wadi Q m^3/sec	Dhar base time (hr)
30.3.93	-	-	1	.5	2	1.0
06.4.93	6	4.6	-	-	-	-
07.4.93	7	5.4	9	3.3	12	2.5
11.4.93	3.5	2.1	-	-	-	-
13.4.93	m	m	-	-	-	-
14.4.93	4.5	3.5	-	-	-	-
15.4.93	9	12	6	2.8	m	m
16.4.93	7.4	1.2	-	-	-	-
17.4.93	2	2.5	-	-	-	-
11.5.93	14	2.2	-	-	-	-
13.5.93	10.2	5.2	-	3.3	-	-
14.5.93	17.5	7	6 & 15	2 & 4	26	6.0
08.8.93	m		5	1.5	4	1.0
09.8.93	m		10	4.5	15	2.0

m = missed
- = no flood

II wadi alSyla

Flood of 6/4

upstream section		Middle section		Downstream section				
distance	level	distance	level	distance	level	upstream	midsectio	downsecti
-1						area	area	area
0	0.79	0	0.83	1	0.912	0.0243	0.151	0.132
0.3	0.952	1	1.132	2	1.176	0.15855	0.367	0.3105
1	1.081	2	1.262	3	1.269	0.335	0.4755	0.3785
2	1.169	3	1.349	4	1.312	0.434	0.526	1.2465
3	1.279	4	1.363	7	1.343	0.5175	1.602	0.4205
4	1.336	7	1.365	8	1.322	0.549	0.5075	0.4185
5	1.342	8	1.31	9	1.339	2.028	0.4595	0.41
9	1.252	9	1.269	10	1.305	0.4955	0.4305	0.3625
10	1.319	10	1.252	11	1.244	0.524	0.4175	0.4575
11	1.309	11	1.243	12	1.495	0.4605	0.1632	0.096195
12	1.192	11.8	0.825	12.33	0.912	0.18795		
12.7	0.925			12.4	0.81	0.021		
13	0.795							
14								

	area	5.7353	5.0997	4.232695
surface	width	13	11.8	11.33
mean depth		0.441177	0.432178	0.373583
friction, (8/f)^.5=5.62log(d/D)+4		17.34251	17.27628	16.80804
K=A(gr)^.58(8/f)^.5		206.9231	181.4098	136.1953
Discharge =	6	kkkkk	dh/kkkk	Q
		57.13493	0.045829	6.241686

Flood of 16/4

upstream section		Middle section		Downstream section				
distance	level	distance	level	distance	level	upstream area	midsectio area	downsecti area
1.3	0.87	0.65	0.65	0	0.43	0.0525		
2	1.02	1.185	0.895	0.37	0.77	0.21	0.041175	
3	1.14	1.795	1.03	0.59	0.92	0.345	0.100575	0.00284
4	1.29	2.335	1.1325	0.67	0.975	0.445	0.177889	0.032545
5	1.34	2.95	1.236	0.9	1.132	1.485	0.535027	0.00224
8	1.39	4.455	1.265	0.91	1.14	0.54	0.215275	0.02322
9	1.43	5	1.315	1	1.2	0.575	0.51975	0.4536
10	1.46	6.1	1.42	2.2	1.38	0.392	0.6204	0.8316
10.7	1.4	7.275	1.426	3.85	1.452	0.28325	1.2552	2.29075
11.25	1.37	9.675	1.41	8.1	1.45	0.26325	0.59475	0.9192
11.9	1.18	11.2	1.16	10.5	1.14	0.01475	0.044713	0.0672
11.95	1.15	11.375	1.141	10.8	1.132	0.03825	0.072844	0.0849
12.1	1.1	11.75	1.0375	11.4	0.975	0.030375	0.023	0.008875
12.25	1.045	11.95	0.9825	11.65	0.92	0.048	0.002188	
12.65	0.935	12	0.895			0.009425		
12.94	0.87							

area	4.7318	4.202785	4.71697
surface wi	11.64	10.815	11.06
mean dep	0.406512	0.388607	0.426489
friction, (8	17.07952	16.93476	17.2337
K=A(gr)^.	161.3888	138.9652	166.2762
kkkkk	dh/kkkk	Q	
103.2864	0.022002	3.65842	

Using the rating curve method. for level at downstream section. with flood mark .912m i.e stage .588 m gives discharge of 5.68 m/sec

0.588	0.910256	8.9744

difference between two method was 9%

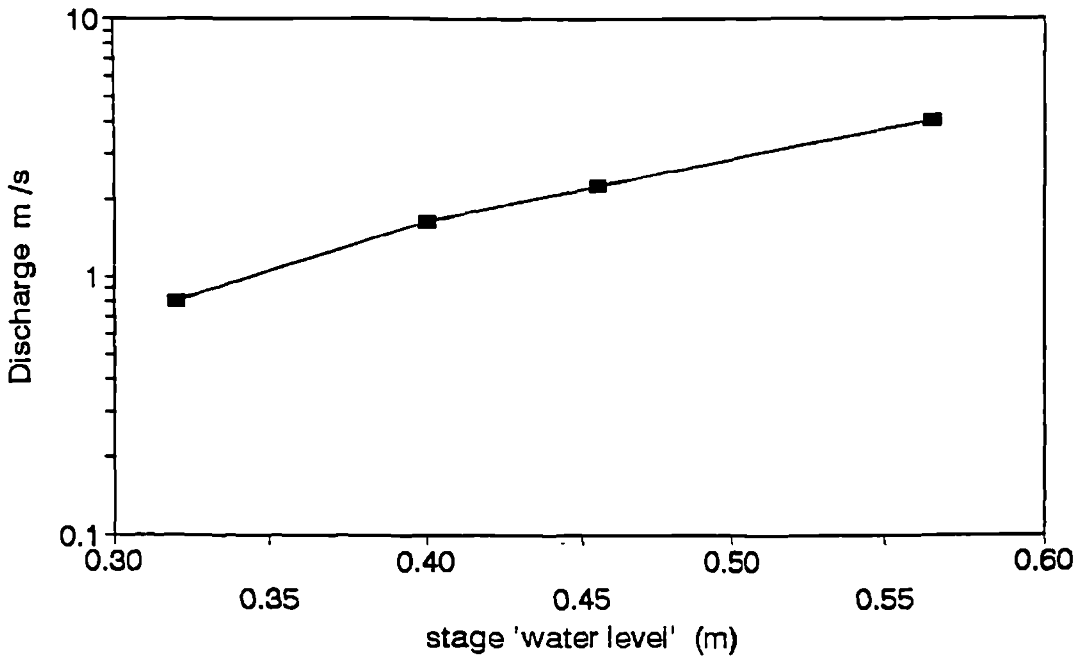
Rating curve
relation between Q = f(H)   Q= a H^b

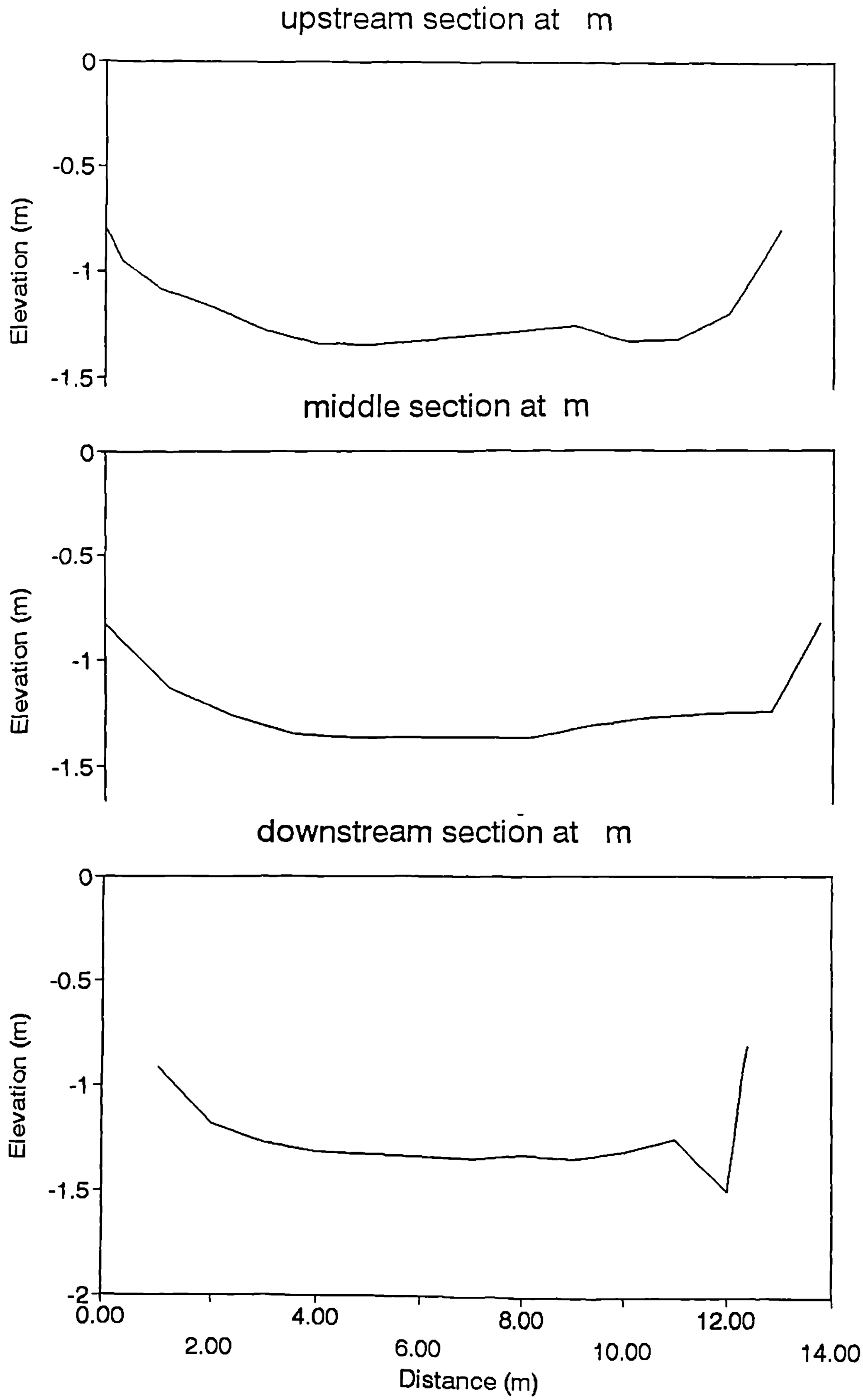
Q	H
4.03	0.565
2.26	0.455
1.63	0.4
0.81	0.32

log Q	log H
0.605	-0.248
0.354	-0.342
0.21	-0.398
-0.09	-0.495
-0.553	-0.568

Regression Output:

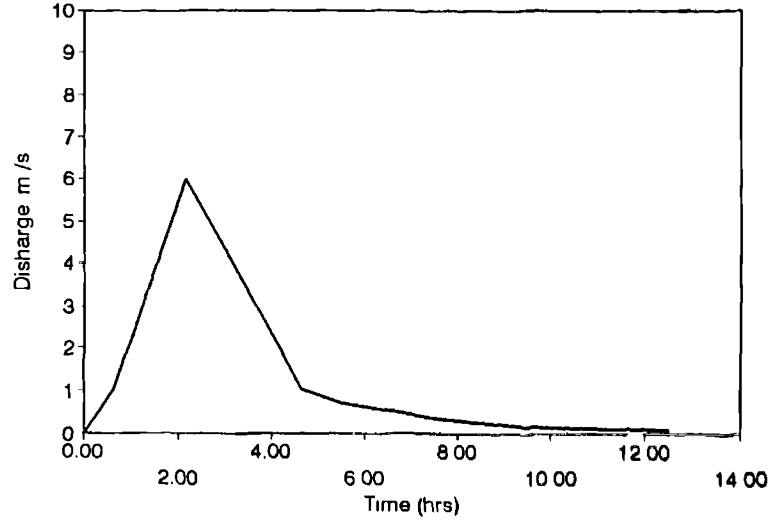
Constant		1.531349
Std Err of Y Est		0.10012
R Squared		0.962127
No. of Observations		5
Degrees of Freedom		3
X Coefficient(s)	3.476715	
Std Err of Coef.	0.398253	



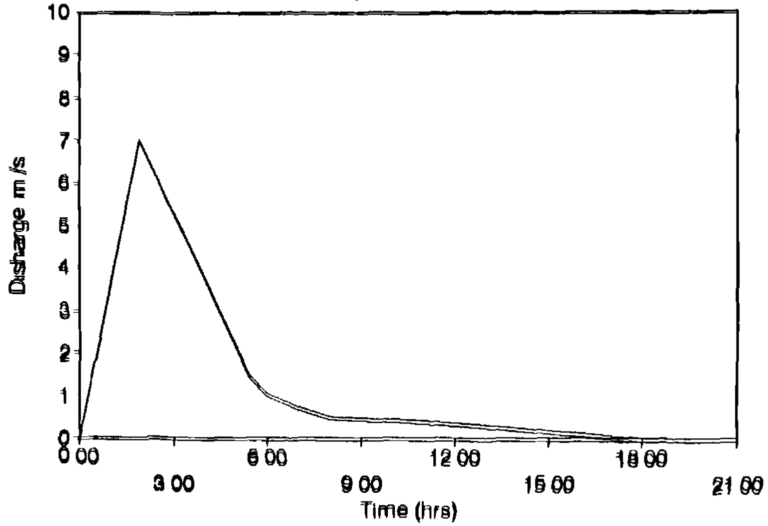


upstream section at m
middle section at m
downstream section at m
Elevation (m)
0
-0.5
-1
-1.5
-2
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
Distance (m)

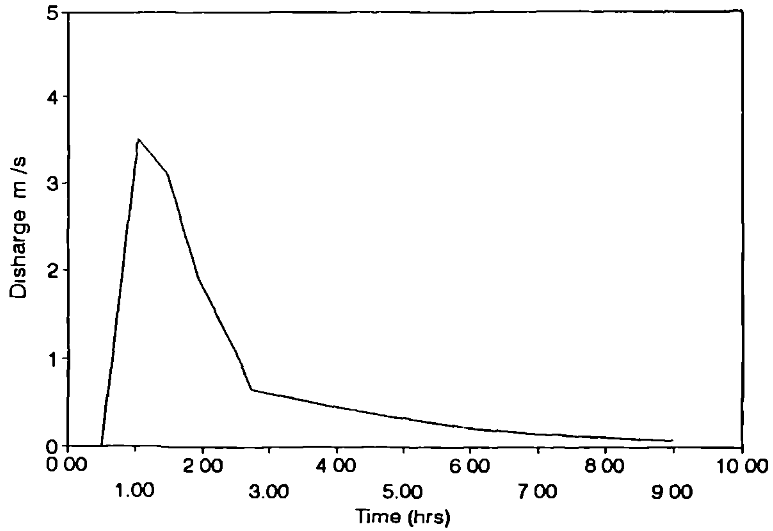
Flood Hydrograph of 6/4/93 in alSyla



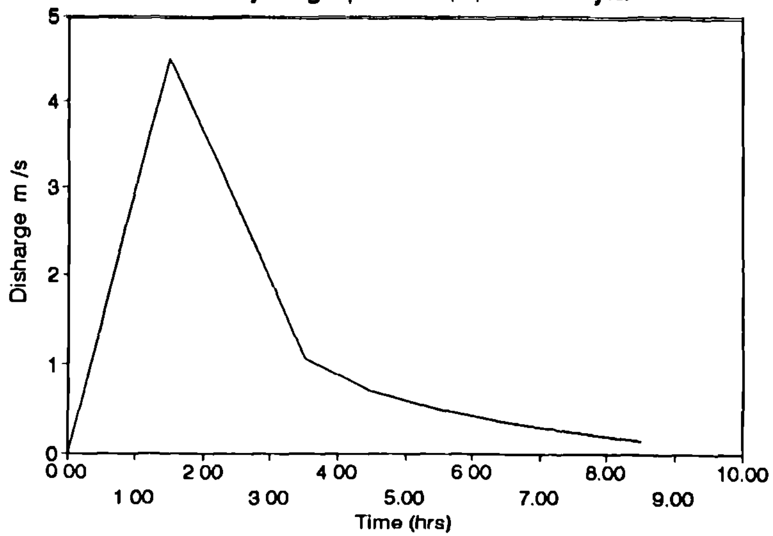
Flood Hydrograph of 7/4/93 in alSyla



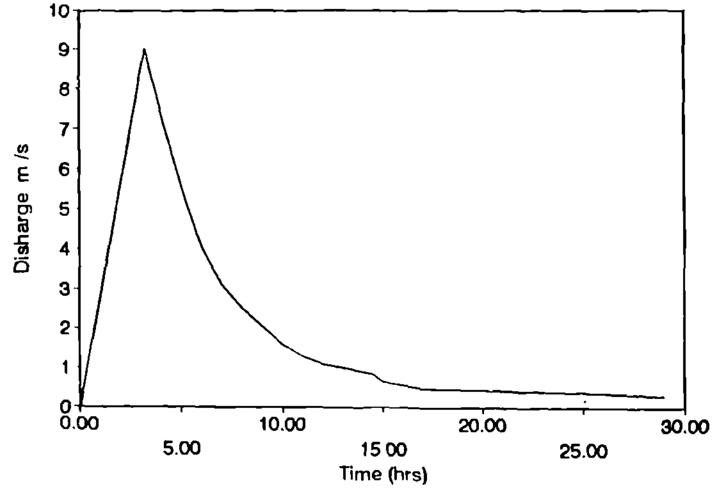
Flood Hydrograph of 11/4/93 in alSyla



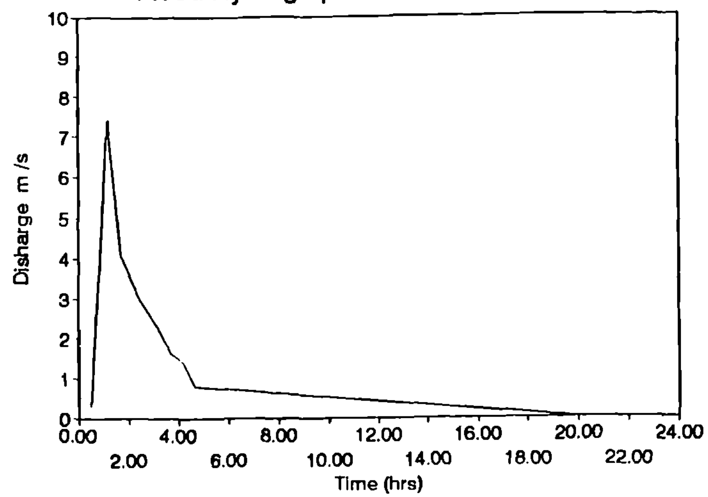
Flood Hydrograph of 14/4/93 in alSyla



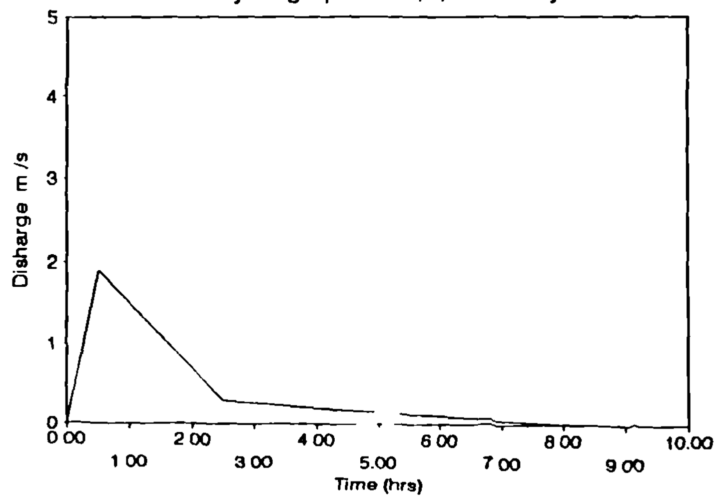
Flood Hydrograph of 15/4/93 in alSyla



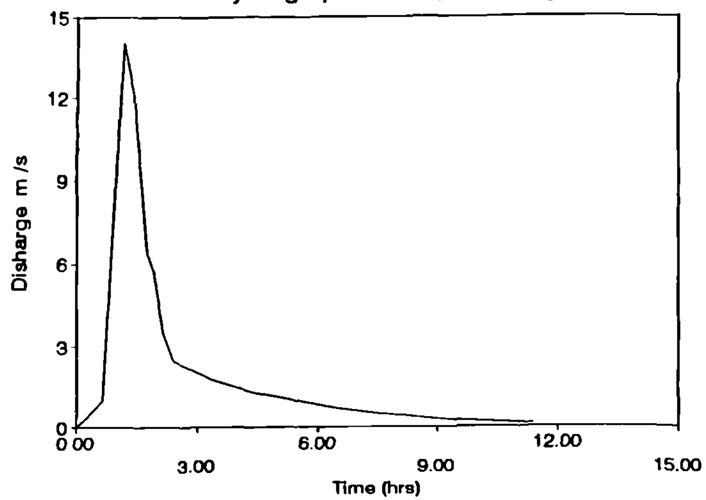
Flood Hydrograph of 16/4/93 in alSyla

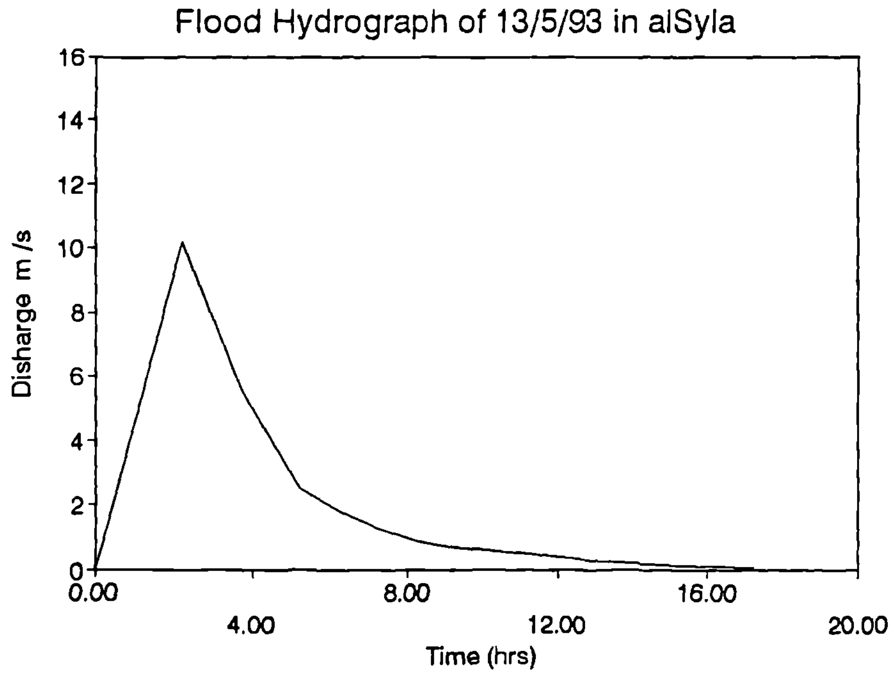


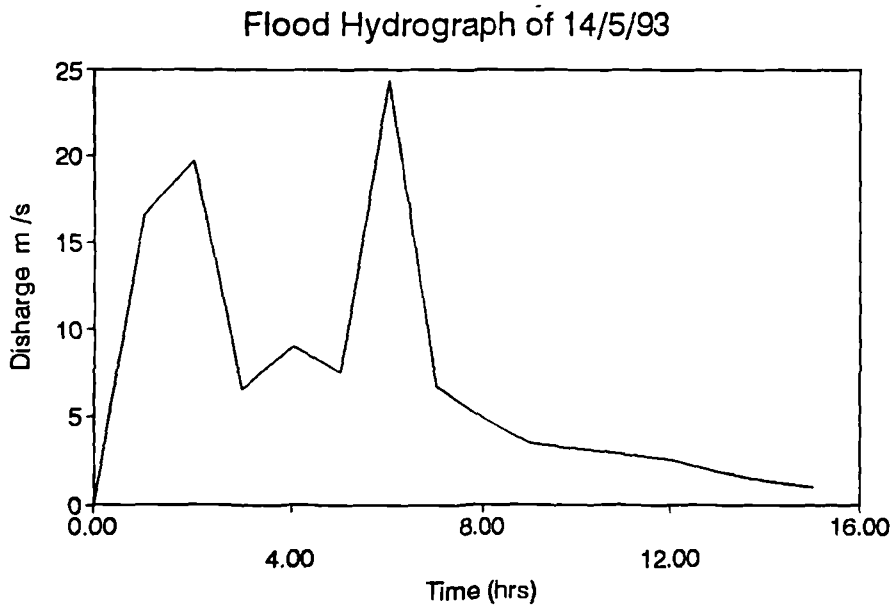
Flood Hydrograph of 17/4/93 in alSyla



Flood Hydrograph of 11/5/93 in alSyla




Flood Hydrograph of 13/5/93 in alSyla
Disharge m /s
0
2
4
6
8
10
12
14
16
0.00
4.00
8.00
12.00
16.00
20.00
Time (hrs)


Flood Hydrograph of 14/5/93
Disharge m /s
0
5
10
15
20
25
0.00
4.00
8.00
12.00
16.00
Time (hrs)

III Wadi Dhar

Slope Area Method
Flood of 14/5

Upstream section Distance	Level	Middle section Distance	Level	Downstream section Distance	Level	upstream area	middle area	downstre am area
0	0.067	0						
0.5	0.35	1	0.32	0.4	0.86			
1	0.672	1.9	0.65	0.8	1.25	0.0805	0	0
2	1.13	2.1	0.75	1	1.46	0.551	0.2835	0.105
3	1.19	3	1.38	2	1.63	0.81	0.735	0.295
4	1.345	4	1.59	3	1.75	0.9175	0.915	0.44
5	1.42	5	1.74	4	1.91	1.0325	0.975	0.58
6	1.39	6	1.71	5	2.05	1.055	0.98	0.73
7	1.4	7	1.75	6	2.14	1.045	1.02	0.845
8	1.365	8	1.79	7	2.1	1.0325	1.04	0.87
9	1.39	9	1.79	8	2.15	1.0275	1.045	0.875
10	1.36	10	1.8	9	2.12	1.025	1.0425	1.77
11	1.255	11	1.785	11	2.18	0.9575	0.985	1.8
12.3	0.985	12	1.685	13	2.04	1.001	0.8125	0.86
12.95	0.35	13	1.44	14	1.79	0.206375	0.555	0.665
		14	1.17	15	1.45		0.021	0.185
		14.1	0.75	15.5	1.25			
				15.5	0.86			

Flood marks

upstream	0.35	m
centre	0.75	m
downstre	1.25	m

Fall of water level		area	10.74138	10.4095	10.02
from upstream to centre	0.4	surface width	12.45	12.2	14.7
from centre to downstream	0.5	mean depth	0.862761	0.853238	0.681633
total fall	0.9	(8/f)^.5=5.62log(d/D)+4	10.38741	10.36032	9.812259
		K=A(gr)^.58(8/f)^.5	324.5988	312.0129	254.2415

overall slope 0.007087

kkkkk	dh/kkkk	Q m3/sec
91.67666	0.103917	26.42011

Calibrated 'n' value

n=A R^.67 S^.5/Q

0.031027 For other flood this n, has been used

n by Limerinos .1129 R^.167/1.16+2log(R/d84) =.032086

To calculate k, recession constant
Q = Qo e^-kt
1=26 e^-k 1/26=e^-4 take ln two sides
-3.258=-4 so k=-3.258/-4 =.6516

For other floods. knowing the stage. (.985)then the area caluculated and su bstituted in the simple equatio

Flood of 30.3
Upstream section

Distance	Level	
0.8	0.6	
1	0.672	
2	1.13	
3	1.19	0.03
4	1.345	0.1375
5	1.42	0.2525
6	1.39	0.275
7	1.4	0.265
8	1.365	0.2525
9	1.39	0.2475
10	1.36	0.245
11	1.255	0.1775
12.3	1.13	0.08125
12.95	0.6	

area	1.96375
width	9.3
mean dep	0.211156

Discharge = 1.819682 m3/s

Flood of 7.4
Downstream section

Distance	Level	
1	1.46	
2	1.63	0.085
3	1.75	0.23
4	1.91	0.37
5	2.05	0.52
6	2.14	0.635
7	2.1	0.66
8	2.15	0.665
9	2.12	0.675
11	2.18	1.38
13	2.04	1.3
14	1.79	0.455
15	1.45	0.16

area	7.135
width	14
mean dep	0.509643

dishcarge = 11.89979

FLOOD MARK READ AT .02
Flood of 8.8 Time 6:30
upstream section

Distance	level	
0	0.067	
0.5	0.35	
1.5	0.965	0.04125
2	1.13	0.195
3	1.19	0.3025
4	1.345	0.4175
5	1.42	0.44
6	1.39	0.43
7	1.4	0.4175
8	1.365	0.4125
9	1.39	0.41
10	1.36	0.3425
11	1.255	0.1885
12.3	0.965	
12.5	0.585	

area 3.59725
width 10.8
mean dep 0.333079

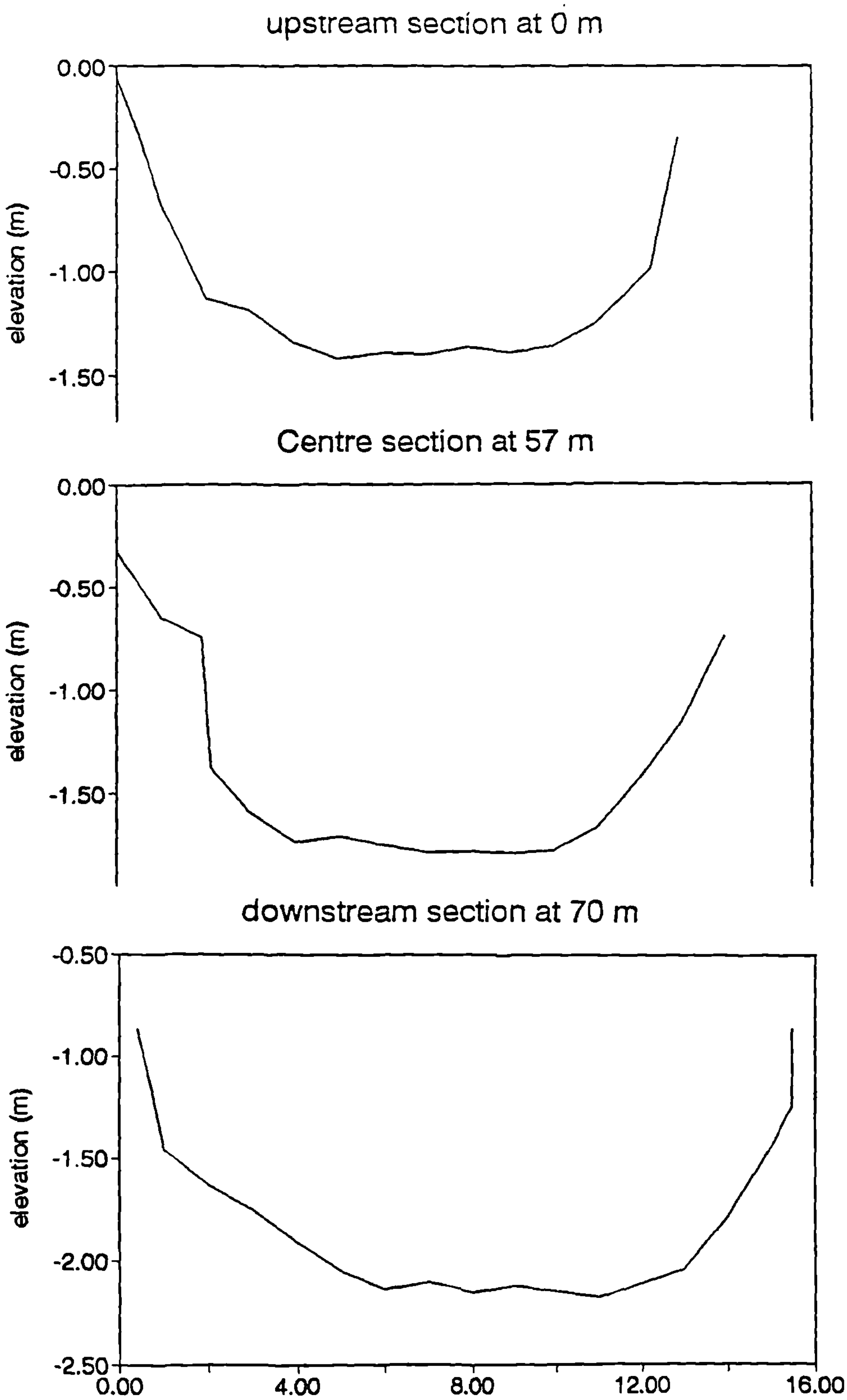
= 4.517607

FLOOD MARK READ AT 0.4
Flood of 9.8 Time 3:15
upstream section

Distance	level	
0	0.067	
0.5	0.35	
0.9	0.585	0.29975
2	1.13	0.575
3	1.19	0.6825
4	1.345	0.7975
5	1.42	0.82
6	1.39	0.81
7	1.4	0.7975
8	1.365	0.7925
9	1.39	0.79
10	1.36	0.7225
11	1.255	0.6955
12.3	0.985	0.04
12.5	0.585	

area 7.82275
width 11.6
mean dep 0.674375

= 15.72663

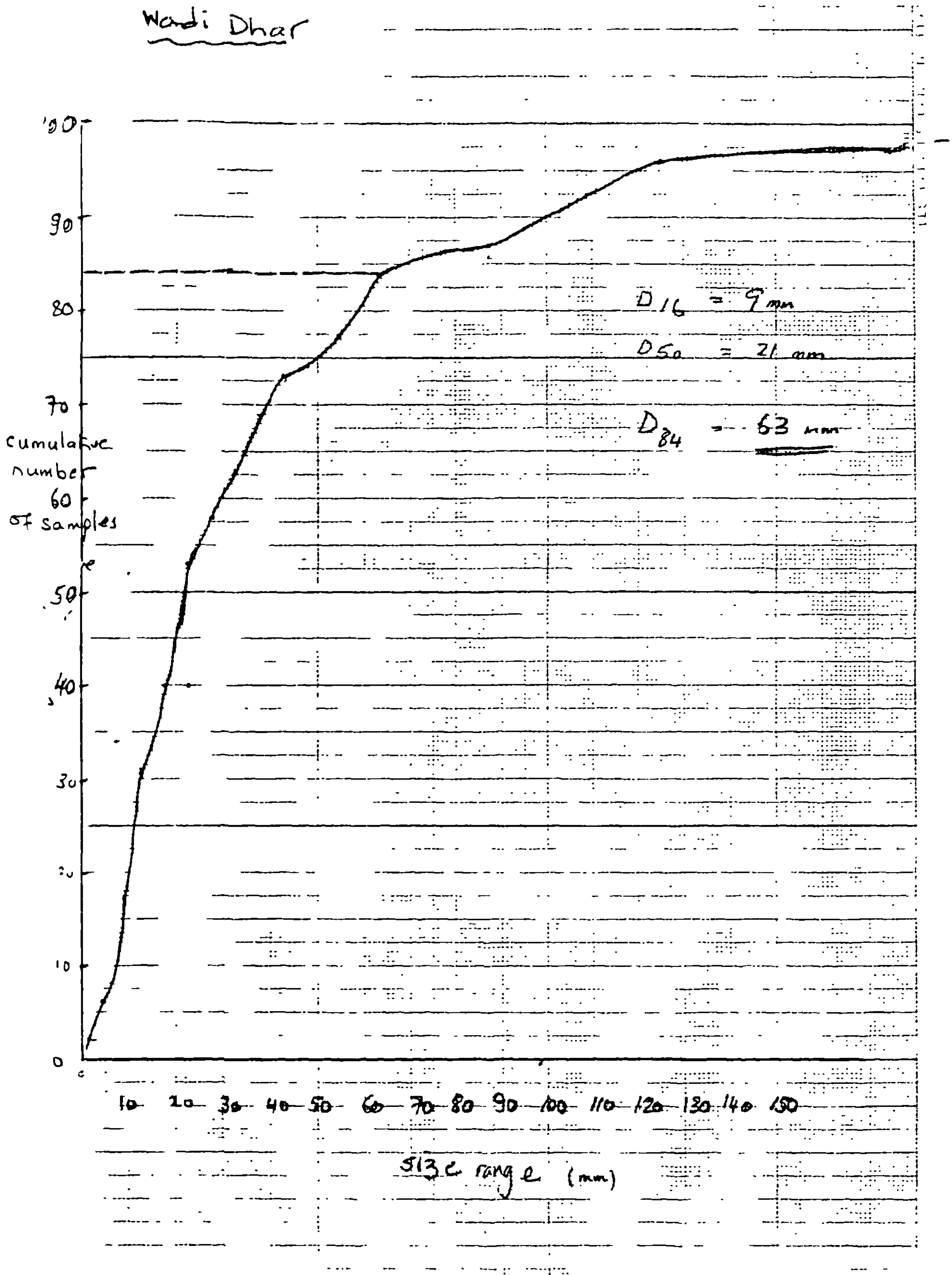

upstream section at 0 m
elevation (m)
0.00
-0.50
-1.00
-1.50
Centre section at 57 m
elevation (m)
0.00
-0.50
-1.00
-1.50
downstream section at 70 m
elevation (m)
-0.50
-1.00
-1.50
-2.00
-2.50
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Distance across channel (m)

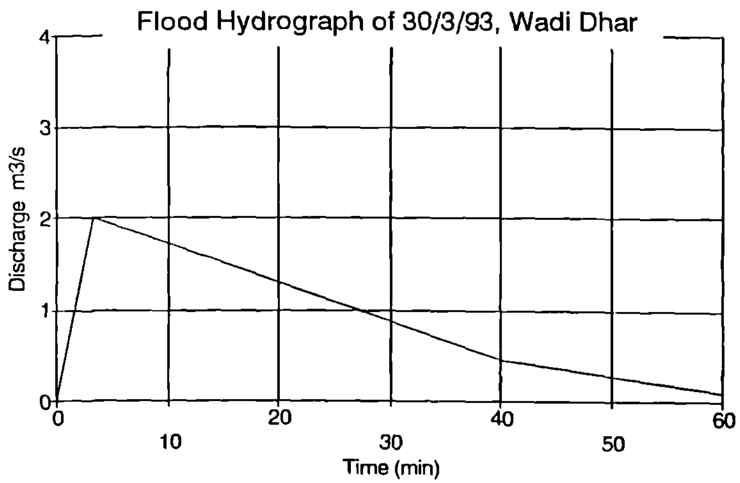
Wadi Dhar

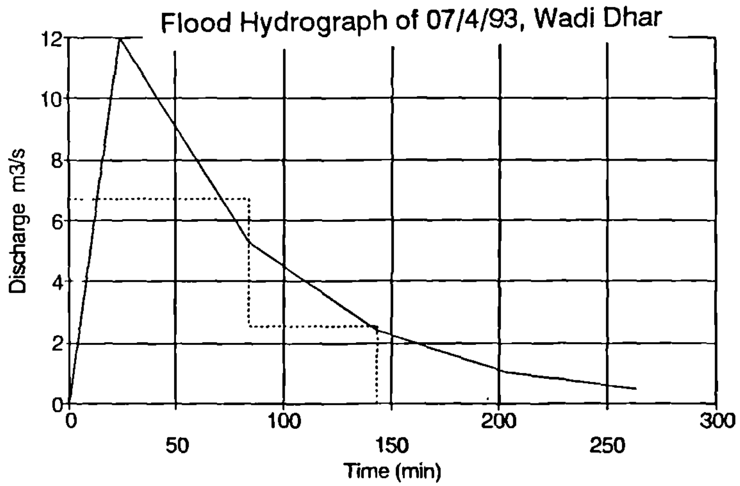
Bed Material Samples

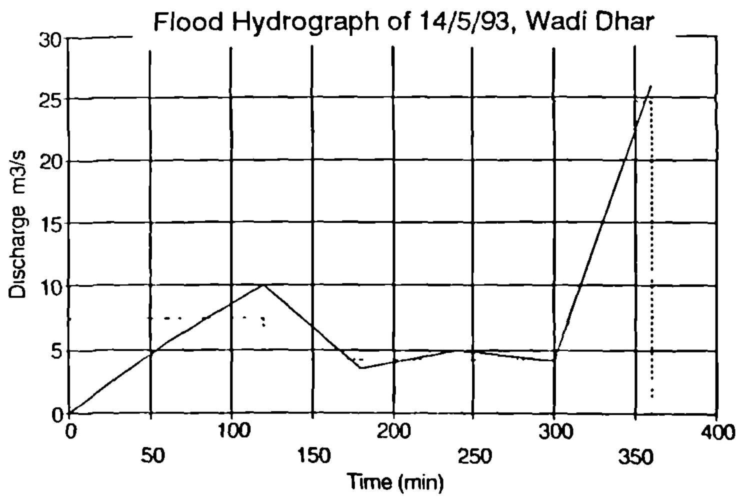
30	75	12	5	32	20	10	10	10	79
52	10	271	7	10	103	23	15	12	10
8	23	13	73	40	15	22	29	93	310
18	64	37	29	20	191	15	94	2	39
121	21	23	22	25	19	120	210	37	25
3	16	41	11	42	35	40	2	15	14
34	71	104	27	23	20	35	142	15	13
45	103	10	43	98	16	74	3	15	23
15	10	26	53	48	24	62	34	114	24
25	40	6	4	50	20	15	63	110	16

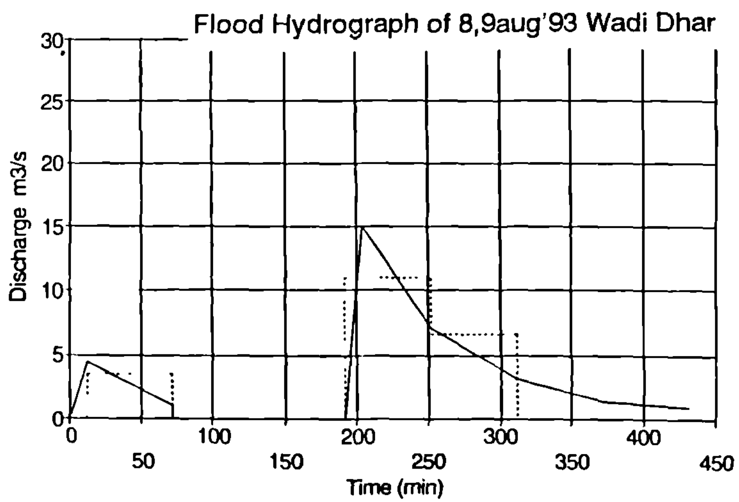
Size range mm	Frequency	Cumulative
0-2.5	2	2
2.5-5	4	6
5-7.5	2	8
7.5-10	9	17
10-15	14	31
15-20	9	40
20-25	13	53
25-30	5	58
30-35	5	63
35-40	6	69
40-45	4	73
45-50	1	74
50-75	10	84
75-100	3	87
100-150	9	96
150-200	1	97
200-300	2	99
300-400	1	100


Wadi Dhar
cumulative number of samples
100
90
80
70
60
50
40
30
20
10
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
size range (mm)
D_{16} = 9 mm
D_{50} = 21 mm
D_{84} = 63 mm









— measured graph ⋯ used graph

IV Wadi alRawna

Wadi survey for flood of 14/5/93 — Time after noon, 5:00 (first peak

upstream section distance	upstream section level	Middle section distance	Middle section level	Downstream section distance	Downstream section level	upstream area	midsectio area	downsecti area
1.15	0.1	0	0.2	0	0.12			
1.9	0.32	1.35	0.93	0.9	1.37	0.008	0.115375	0.198
2	0.48	2	1.285	2	1.73	0.52	0.3775	0.67
4	0.68	3	1.33	4	1.68	0.7	1.46	0.625
6	0.66	7	1.26	6	1.685	0.54	0.63	0.705
8	0.52	9	1.23	8	1.76	0.4	0.5	0.69
10	0.52	11	1.13	10	1.67	0.38	0.395	0.56
12	0.5	13	1.125	12	1.63	0.48	0.0741	0.56
14	0.62	13.76	0.93	14	1.67	0.285		0.225
15.9	0.32	15	0.61	15.5	1.37			
16	0.3	17	0.15					
16.7	0.15	18.5	0.01					

Flood marks

upstream 0.32

centre 0.93

down stre 1.37

fall of water level

from upstream to cetre 0.66

from centre to downstream 0.44

Total fall 1.05

overall slope 0.010825

	area	3.313	3.551975	4.233
surface	width	14	12.41	14.6
mean	depth	0.236643	0.286219	0.289932
	Distance	0	50	47
	friction, (8	9.298141	9.762379	9.793836
K=A(gr)^.58(8/f)^.5		46.93521	58.10441	69.91708
			Q	
	144.147	0.085348	5.967263	
	Dishcarge =6		m3/s	

Calibrated 'n' 0.026

also according to chow, 1959 for similar condition it should range between .025 and .03 and max .033

Flood of 14/5 at 7:00 O'clock

upstream section		Middle section		Downstream section				
distance	level	distance	level	distance	level	upstream area	midsectio area	downsection area
1.1	0.12	1	0.74	0.8	1.25	0.08	0.03325	0.006
1.9	0.32	1.35	0.93	0.9	1.37	0.035	0.238875	0.33
2	0.62	2	1.285	2	1.73	1.06	0.5675	0.91
4	0.68	3	1.33	4	1.68	1.1	2.22	0.865
6	0.66	7	1.26	6	1.685	0.94	1.01	0.945
8	0.52	9	1.23	8	1.76	0.8	0.88	0.93
10	0.52	11	1.13	10	1.67	0.78	0.775	0.8
12	0.5	13	1.125	12	1.63	0.88	0.2185	0.8
14	0.62	13.76	0.93	14	1.67	0.665	0.0798	0.315
15.9	0.32	14.6	0.74	15.5	1.25	0.07		
16.6	0.12	16.2	0.48					
16.9	0.08	18.5	0.01					

area	6.41	6.022925	5.901
surface wi	15.5	13.6	14.7
mean dep	0.413548	0.442862	0.401429
friction.	10.66061	10.82776	10.58801
K=	137.6379	135.9299	123.9877
		Q	
83.28897	0.116478	14.4419	
discharge	=15	m3/s	

Flood of 30.3

Middle section

distance	level	
1	0.74	
1.45	1.125	0.044
2	1.285	0.1825
3	1.33	0.68
7	1.26	0.24
9	1.23	0.11
11	1.13	0.005
13	1.125	
13.76	0.93	
14.6	0.74	
16.2	0.48	
18.5	0.01	

area 1.2615
Width 11.55
mean dep 0.109221

dishcarge = 1.154183

flood of 15/4/93

Middle section

distance	level	
1	0.74	
1.35	0.93	0.115375
2	1.285	0.3775
3	1.33	1.46
7	1.26	0.63
9	1.23	0.5
11	1.13	0.395
13	1.125	0.0741
13.76	0.93	
14.6	0.74	
16.2	0.48	
18.5	0.01	

area 3.551975
Width 12.41
mean dep 0.286219

discharge = 6.196988

flood of 7/4/93

Middle section

distance	level	
1.1	0.85	0.01
1.35	0.93	0.167375
2	1.285	0.4575
3	1.33	1.78
7	1.26	0.79
9	1.23	0.66
11	1.13	0.555
13	1.125	0.1349
13.76	0.93	0.0176
14.2	0.85	
18.5	0.01	

area 4.572375
Width 13.1
mean dep 0.349036

discharge = 9.111463

flood of 8/8/93

Middle section

distance	level	
1	0.74	
1.45	0.98	0.083875
2	1.285	0.3275
3	1.33	1.26
7	1.26	0.53
9	1.23	0.4
11	1.13	0.295
13	1.125	0.0145
13.2	0.98	
14.6	0.74	
16.2	0.48	
18.5	0.01	

area	2.910875
Width	11.75
mean dep	0.247734

Discharge = 4.61017

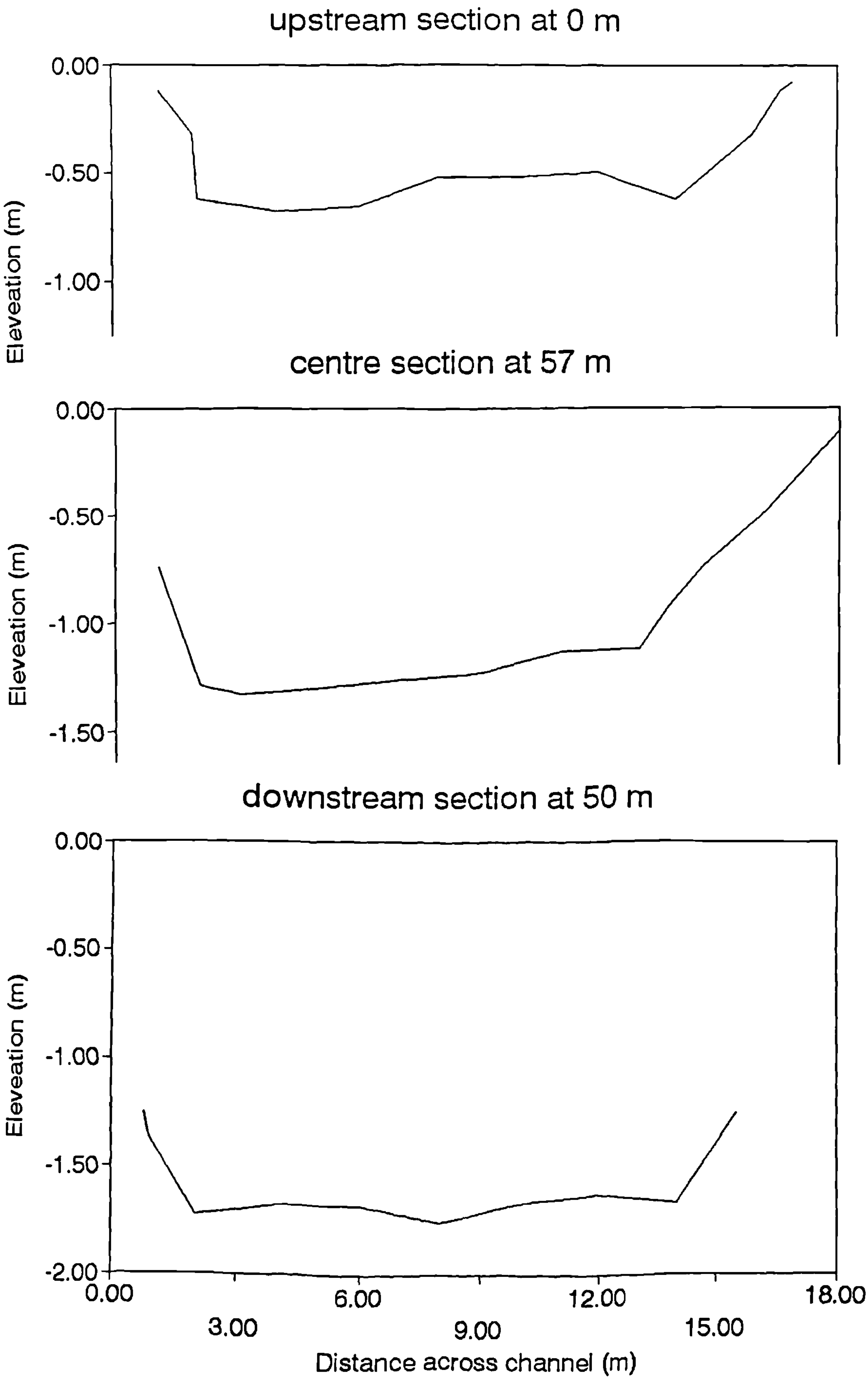
flood of 9/8/93

Middle section

distance	level	
1.2	0.83	0.01875
1.45	0.98	0.166375
2	1.285	0.4775
3	1.33	1.86
7	1.26	0.83
9	1.23	0.7
11	1.13	0.595
13	1.125	0.0445
13.2	0.98	0.045
13.8	0.83	
16.2	0.48	
18.5	0.01	

area	4.737125
Width	12.6
mean dep	0.375962

discharge = 9.921664

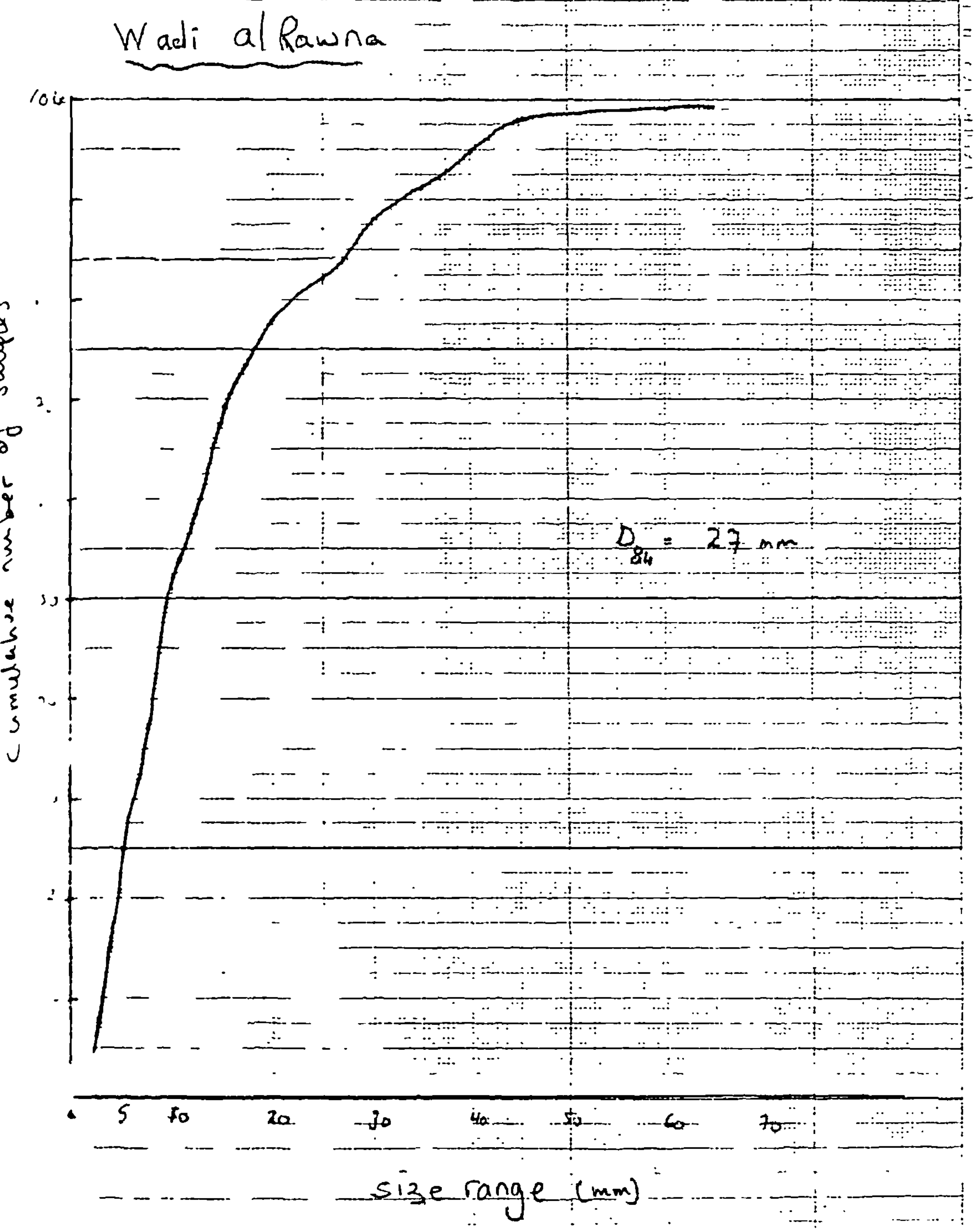

upstream section at 0 m
0.00
-0.50
-1.00
Elevation (m)
centre section at 57 m
0.00
-0.50
-1.00
-1.50
Eleveation (m)
downstream section at 50 m
0.00
-0.50
-1.00
-1.50
-2.00
Eleveation (m)
0.00
3.00
6.00
9.00
12.00
15.00
18.00
Distance across channel (m)

Wadi al-Rawna

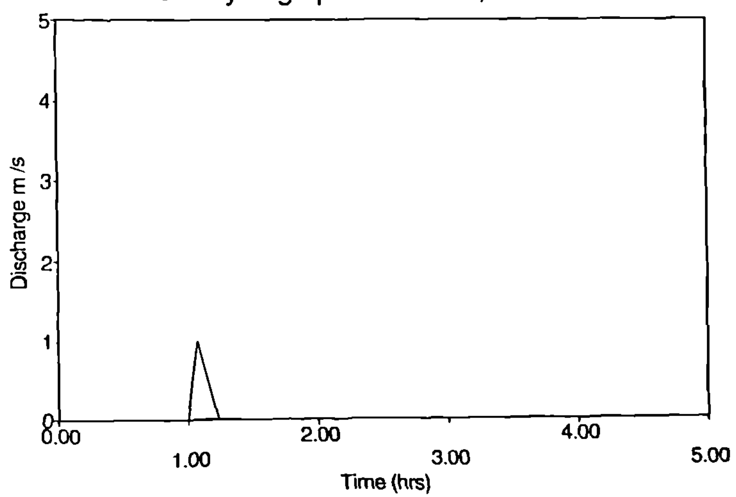
Bed Material Samples

43	4	11	11	64	26	12	30	18	12
5	1	9	5	45	14	11	23	6	14
3	2	6	4	35	21	28	20	7	7
6	2	5	5	20	8	6	43	4	5
36	19	6	8	30	12	18	15	2	4
6	28	2	5	36	9	12	7	12	8
3	16	11	6	23	6	9	9	31	9
3	14	35	60	38	8	8	3	9	5
15	9	20	15	22	5	17	5	12	4
8	8	1	17	27	40	8	7	11	3

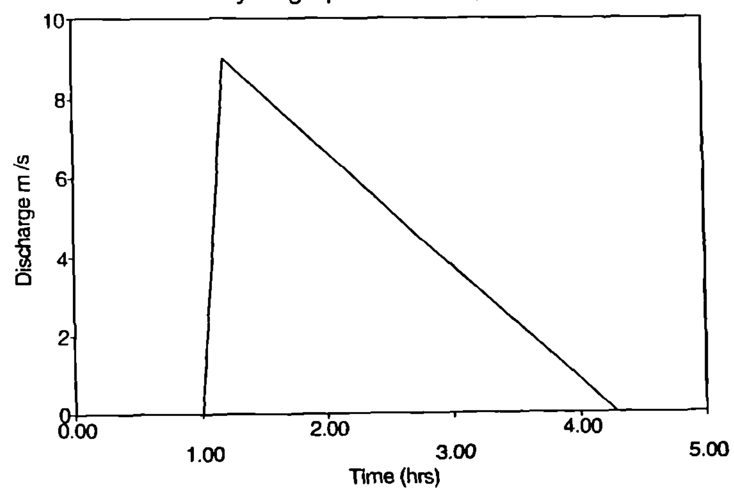
Size range mm	number in range	Cumulative
0-2.5	6	6
2.5-5	19	25
5-7.5	12	37
7.5-10	15	52
10-15	17	69
15-20	9	78
20-25	4	82
25-30	6	88
30-35	3	91
35-40	4	95
40-45	3	98
45-60	1	99
60-70	1	100


Wadi al Rawna
100
Cumulative number of samples
D_{84} = 27 mm
5
10
20
30
40
50
60
70
size range (mm)

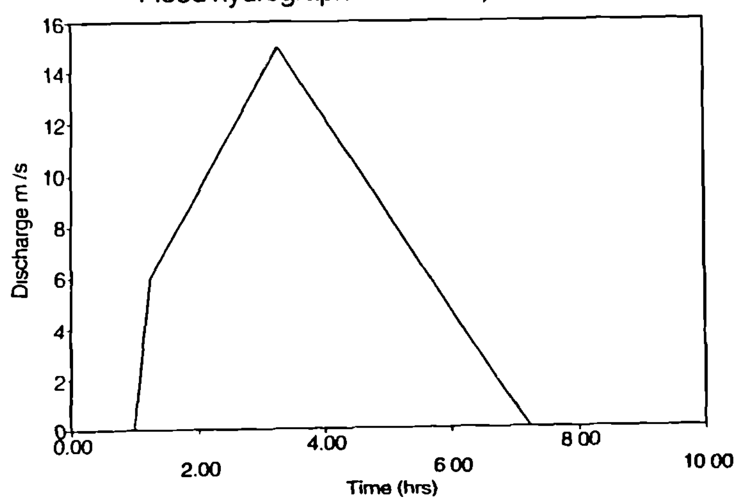
Flood hydrograph of 30/3/93 , alRawna



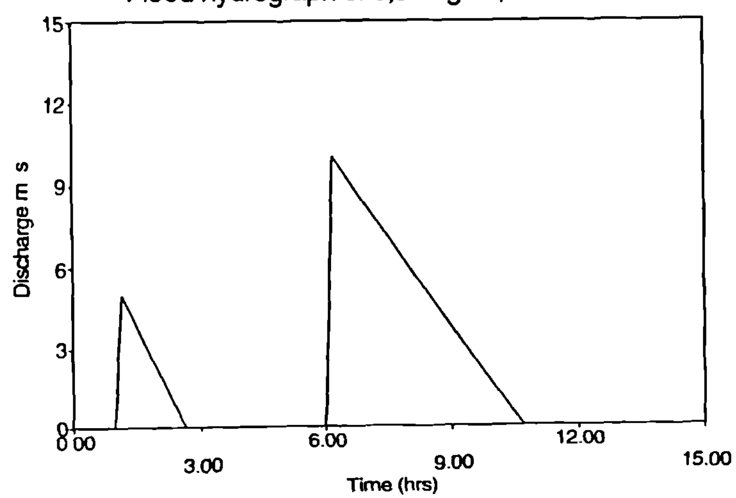
Flood hydrograph of 7/4/93 , alRawna



Flood hydrograph of 14/5/93 , alRawna



Flood hydrograph of 8,9 aug'93, alRawna



Appendix D

(D-1 TO D-17)

Wadi Recharge data

CHANNEL WATER BALANCE
WADI DHAR

			Rain or TI	soil content		coefficient soil content/MAXTST	actual evaporation ETo' coeff		deep percolation			potential ev
1	mar		0 0	0	0							5 27
2			0 0	0	0	0	0	0	0			5 93
3			0 0	0	0	0	0	0	0			5 20
4			0 0	0	0	0	0	0	0			5 78
5			0 0	0	0	0	0	0	0			6 88
6			0 0	0	0	0	0	0	0			7 21
7			0 0	0	0	0	0	0	0			5 42
8			0 0	0	0	0	0	0	0			5 20
9			0 0	0	0	0	0	0	0			5 88
10			0 0	0	0	0	0	0	0			6 05
11			0	0	0	0	0	0	0			6 66
12			0	0	0	0	0	0	0			5 46
13			0 0	0	0	0	0	0	0			4 93
14			0	0	0	0	0	0	0			5 39
15			0	0		0	0	0	0			4 83
16			0 0	0	0	0	0	0	0			6 34
17			0	0	0	0	0	0	0			4 85
18			0 0	0	0	0	0	0	0			7 12
19			0	0	0	0	0	0	0			6 15
20			0 0	0	0	0	0	0	0			6 13
21			0 0	0	0	0	0	0	0			5 90
22			0	0	0	0	0	0	0			6 41
23			0	0	0	0	0	0	0			5 70
24			0		0	0	0	0	0			7 39
25			0	0	0	0	0	0	0			6 51
26			0 0	0	0	0	0	0	0			5 98
27			1 7	1 7	1 7	0 034	0 1932642	1.5067358	0			5 68
28			9	2 4067358	2 4067358	0 0481347	0.2103327	2 1964031	0			4 37
29			5 6	7 7964031	7 7964031	0 1559281	0 7266292	7 0697739	0			4 66
30		12 2	149 5	156 56977	50	1	5 6728629	44 327137	106 56977	2264 6077	4795 6398	5 67
31				44 327137	44 327137	0 8865427	4 5326379	39 794499	0			5 11
1	apr			39 794499	39 794499	0 79589	5.2585789	34 53592	0			6 61
2			1 6	36 13692	36 13692	0 7227184	3 6210738	32.514847	0			5 01
3				32 514847	32 514847	0 6502969	2 8918983	29 622948	0			4 45
4			0	29 622948	29 622948	0 592459	2 5952764	27 027672	0			4 38
5			2 4	29 427672	29 427672	0 5885534	2.7196494	26 708022	0			4 62
6		14 8	198 4	225 10802	50	1	4 1589178	45 841082	175 10802	3721.0455	7879 861	4 16
7		21 7	384 4	430 24108	50	1	4 6590678	45 340932	380.24108	8080 123	17110 849	4 66
8				45 340932	45 340932	0 9068186	4 6083821	40 73255	0			5 08
9			0	40 73255	40 73255	0 814651	3 3301447	37 402405	0			4 09
1			2	37 602405	37 602405	0 7520481	3 6084436	33 993962	0			4 80
11			5	34 493962	34 493962	0 6898792	3.3168712	31 177091	0			4 81
12			1 8	32 977091	32 977091	0 6595418	3 1224865	29 854604	0			4 73
13			5 8	35 654604	35 654604	0 7130921	2.7524676	32 902137	0			3 86
14			39 5	72 402137	50	1	3 8708774	46 129123	22 402137	476 0454	1008 0961	3 87
15		20	302 7	348 82912	50	1	3 0013572	46 998643	298 82912	6350 1189	13447 311	3 00
16			9	47 898643	47 898643	0 9579729	3 6353203	44 263323	0			3 79
17			5 7	49 963323	49 963323	0 9992665	3 9521705	46 011152	0			3 96
18			0 0	46 011152	46 011152	0 920223	3 653878	42 357274	0			3 97
19			0.5	42 857274	42 857274	0 8571455	3 8319745	39 025299	0			4 47
20			0	39 025299	39 025299	0 780506	3.2131778	35 812122	0			4 12
21			0	35 812122	35 812122	0 7162424	3 3548449	32 457277	0			4 68
22				32 457277	32 457277	0 6491455	4 2070891	28.250188	0			6 48
23			0	28.250188	28.250188	0 5650038	3 0616914	25 188496	0			5 42
24			0	25 188496	25 188496	0 5037699	3 5708224	21 617674	0			7 09
25			2	21 817674	21 817674	0 4363536	2.1490866	19 668587	0			4 93
26			0	19 668587	19 668587	0 3933717	1 8480119	17 820575	0			4 70
27			5 5	23 320575	23 320575	0 4664115	2 3018976	21 018678	0			4 94
28				21 18678	21 018678	0 4203736	1 9982594	19 020418	0			4 75
29			2 1	21 120418	21 120418	0 4224084	1 6045749	19 515843	0			3 80
30			0	19 515843	19 515843	0.3903169	1 883468	17 632375	0			4 83
1	may			17 632375	17 632375	0 3526475	1 7814174	15 850958	0			5 05
2			0 0	15 850958	15 850958	0 3170192	2.2555487	13 595409	0			7 11
3			2 4	15 995409	15 995409	0 3199082	2.0186174	13 976792	0			6 31
4			5.5	19 476792	19 476792	0 3895358	2 6566282	16 820164	0			6 82
5			0 0	16 820164	16 820164	0 3364033	1 9157318	14 904432	0			5 69
6		10 8	148 6	163 50443	50	1	7 0602957	42 939704	0			7 06
7			0	42 939704	42 939704	0 8587941	5 0956539	37 84405	0			5 93
8			0 0	37 84405	37 84405	0 756881	4 5858802	33.25817	0			6.06
9			0 0	33.25817	33.25817	0 6651634	3 3052256	29 952945	0			4 97
10			0 0	29 952945	29 952945	0.5990589	3 4091678	26 543777	0			5 69
11			0 0	26 543777	26 543777	0 5308755	4 8002475	21 743529	0			9.04
12			54 0	75 743529	50	1	6.9997555	43 000244	25 743529	547 05	1158 4588	7 00
13		12 5	322 4	365 40024	50	1	5.3860175	44 613983	315 40024	6702.2552	14193 011	5 39
14		26 4	482 0	526 61398	50	1	5 6519745	44 348025	476 61398	10128 047	21447 629	5 65
15			0 0	44 348025	44 348025	0 8869605	3 9810286	40 366997	0			4 49
16			6 1	46 466997	46 466997	0 9293399	4 451584	42 015413	0			4 79
17			0 0	42 015413	42 015413	0 8403083	4 4754547	37 539958	0			5.33
18			0 0	37.539958	37 539958	0 7507992	3 3881312	34 151827	0			4 51
19			0 0	34 151827	34 151827	0 6830365	3 9751089	30 176718	0			5 82
20			0 0	30 176718	30 176718	0 6035344	3 5131679	26 66355	0			5.82
21			0 0	26 66355	26 66355	0 533271	2.8677879	23 795762	0			5.38
22			0 0	23 795762	23 795762	0 4759152	2.5762094	21.219553	0			5 41
23			0 0	21.219553	21.219553	0 4243911	2.6957358	18 523817	0			6 35
24			0 0	18 523817	18 523817	0 3704763	1 886911	16 636906	0			5 09
25			0 0	16 636906	16 636906	0 3327381	1 7667511	14 870155	0			5 31
26			0 0	14 870155	14 870155	0 2974031	1 7700997	13 100055	0			5 95
27			0 0	13 100055	13 100055	0.2620011	1 6726018	11 427453	0			6 38
28			0 0	11 427453	11 427453	0.2285491	1 4780503	9 9494029	0			6 47
29			0 0	9 9494029	9 9494029	0 1989881	1 6379153	8 3114875	0			8 23
30			0 0	8.3114875	8 3114875	0 1662298	0 8674189	7 4440687	0			5 22
31			0 0	7 4440687	7 4440687	0 1488814	0 9714069	6 4726618	0			6 52

1	jun		0 0	6.472662	6 472662	0 129453	0.755442	5 71722	0			5.84
2			0 0	5 71722	5 71722	0 114344	0 644536	5.072684	0			5 64
3			0 0	5 072684	5 072684	0.101454	0.666422	4 406261	0			6 57
4			0 0	4 406261	4 406261	0 088125	0.617483	3.788779	0			7.01
5			0 7	4 488779	4 488779	0 089776	0.603411	3.885367	0			6.72
6			0 0	3.885367	3 885367	0 077707	0 4661	3.419267	0			6.00
7			0 0	3 419267	3 419267	0 068385	0.386741	3.032526	0			5.66
8			0 0	3 032526	3 032526	0.060651	0.370954	2 661572	0			6.12
9			0 0	2 661572	2 661572	0 053231	0 403807	2.257765	0			7.59
10			0 0	2 257765	2 257765	0 045155	0.263042	1.994723	0			5.83
11			0 0	1 994723	1 994723	0.039894	0 276157	1 718566	0			6 92
12			0 0	1 718566	1 718566	0.034371	0 239361	1.479205	0			6 96
13			0 0	1 479205	1 479205	0.029584	0 197212	1 281993	0			6.67
14			0 0	1 281993	1 281993	0 02564	0 162692	1.119301	0			6.35
15			0 0	1 119301	1 119301	0 022386	0.153725	0 965576	0			6.87
16			0 0	0 965576	0 965576	0 019312	0.16649	0.799086	0			8 62
17			0 0	0.799086	0 799086	0 015982	0 119564	0 679522	0			7.48
18			0 0	0 679522	0 679522	0 01359	0 099732	0.57979	0			7.34
19			0 0	0 57979	0 57979	0 011596	0.090124	0.489666	0			7.77
20			0 0	0 489666	0 489666	0 009793	0.076383	0.413283	0			7.80
21			0 0	0 413283	0 413283	0 008266	0.061149	0.352134	0			7.40
22			0 0	0 352134	0 352134	0 007043	0 03907	0 313064	0			5.55
23			0 0	0 313064	0 313064	0 006261	0 036581	0.276483	0			5.84
24			0 0	0 276483	0 276483	0 00553	0 036346	0 240137	0			6.57
25			0 0	0 240137	0 240137	0 004803	0 029414	0 210723	0			6.12
26			0 0	0 210723	0 210723	0.004214	0.035831	0.174891	0			8.50
27			0 0	0 174891	0 174891	0.003498	0 03109	0.143801	0			8 89
28			0 0	0 143801	0 143801	0 002876	0.022373	0.121428	0			7 78
29			0 0	0 121428	0 121428	0 002429	0 015778	0.10565	0			6.50
30			0 0	0 10565	0 10565	0 002113	0 014078	0.091572	0			6.66
1	jul		0 0	0 091572	0 091572	0 001831	0 012352	0 079219	0			6.74
2			0 0	0 079219	0 079219	0 001584	0 009796	0.069424	0			6.18
3			0 0	0 069424	0 069424	0 001388	0.008003	0 061421	0			5.76
4			0 0	0 061421	0 061421	0 001228	0 011629	0 049792	0			9.47
5			0 0	0 049792	0 049792	0 000996	0 008737	0 041055	0			8.77
6			0 0	0 041055	0 041055	0 000821	0 00587	0.035185	0			7.15
7			0 0	0 035185	0 035185	0 000704	0 006506	0.028679	0			9.25
8			0 0	0 028679	0 028679	0 000574	0 004656	0 024023	0			8.12
9			0 0	0 024023	0 024023	0 00048	0 003435	0 020588	0			7.15
10			0 0	0 020588	0 020588	0 000412	0 003361	0 017227	0			8.16
11			0 0	0 017227	0 017227	0 000345	0 002455	0 014772	0			7.13
12			0 0	0 014772	0 014772	0 000295	0 002164	0.012608	0			7.32
13			0 0	0 012608	0 012608	0 000252	0.001926	0.010682	0			7.64
14			0 0	0 010682	0 010682	0 000214	0.001463	0 009219	0			6 85
15			0 0	0 009219	0 009219	0 000184	0 001328	0.007891	0			7 20
16			0 0	0 007891	0 007891	0 000158	0 000992	0.006899	0			6.29
17			0 0	0 006899	0 006899	0 000138	0 001105	0 005794	0			8.01
18			0 0	0 005794	0 005794	0 000116	0 000921	0 004873	0			7 95
19			0 0	0 004873	0 004873	9 75E-05	0 000576	0 004297	0			5.91
20			0 0	0 004297	0 004297	8 59E-05	0 000495	0 003802	0			5.76
21			0 7	0 703802	0 703802	0 014076	0 118881	0.584921	0			8.45
22			0 0	0 584921	0 584921	0 011698	0.091901	0.493021	0			7.86
23			0 0	0 493021	0 493021	0 00986	0.101168	0.391852	0			10.26
24		10 8	1 0	1 391852	1 391852	0 027837	0.221046	1.170806	0			7 94
25			0 0	1 170806	1 170806	0 023416	0 156079	1.014727	0			6.67
26			0 0	1 014727	1 014727	0 020295	0 175387	0.83934	0			8.64
27			0 0	0 83934	0 83934	0 016787	0.143369	0.695971	0			8.54
28			0 0	0 695971	0 695971	0 013919	0 084115	0.611857	0			6.04
29			0 0	0 611857	0 611857	0 012237	0 091318	0.520539	0			7 46
30			0 0	0 520539	0 520539	0 010411	0 076989	0 44355	0			7.40
31			0	0 44355	0 44355	0 008871	0.057122	0 386429	0			6.44
1	aug		0 0	0 386429	0 386429	0 007729	0.04589	0.340538	0			5.94
2			0 0	0 340538	0 340538	0 006811	0 049353	0.291186	0			7.25
3			0 0	0 291186	0.291186	0.005824	0 056171	0 235014	0			9.65
4			0 0	0 235014	0 235014	0 0047	0 033496	0.201518	0			7.13
5			0 0	0 201518	0 201518	0 00403	0 030787	0.170731	0			7.64
6			0 0	0 170731	0.170731	0 003415	0.023845	0.146886	0			6.98
7			0 0	0 146886	0 146886	0.002938	0 026173	0.120713	0			8.91
8			0 0	0 120713	0 120713	0 002414	0.012865	0.107849	0			5.33
9			0 0	0.107849	0 107849	0.002157	0.012054	0.095794	0			5.59
10		21 6	160 4	160 4958	50	1	7.191794	42.80821	110.4958	2348.036	4972.311	7.19
11		9 7	458 4	501.2082	50	1	5.898735	44.10126	451.2082	9588.174	20304.37	5.90
12			0 0	44 10126	44 10126	0 882025	6.386115	37.71515	0			7.24
13			0 0	37.71515	37 71515	0 754303	5.080871	32 63428	0			6.74
14			1 6	34.23428	34 23428	0 684686	5.750488	28.48379	0			8.40
15			0 0	28 48379	28 48379	0 569676	3.817706	24.66608	0			6.70
16			0 0	24 66608	24 66608	0.493322	3.732118	20.93397	0			7.57
17			0 0	20 93397	20 93397	0.418679	2.730271	18.2037	0			6.52
18			0.0	18.2037	18 2037	0.364074	1.988979	16.21472	0			5.46
19			0 0	16 21472	16 21472	0.324294	2 018264	14.19645	0			6.22
20			0 0	14.19645	14 19645	0.283929	2.278643	11.91781	0			8.03
21			0 0	11 91781	11.91781	0.238356	1.387555	10.53025	0			5.82
22			0.0	10.53025	10 53025	0.210605	1.418522	9.111732	0			6.74
23			0 0	9.111732	9.111732	0.182235	1.579384	7.532348	0			8.67
24			0 0	7.532348	7 532348	0.150647	0 934871	6.597478	0			6.21
25			0.0	6.597478	6.597478	0.13195	0.956178	5.6413	0			7.25
26			0 0	5 6413	5 6413	0.112826	0.83956	4.801741	0			7.44
27			0.0	4 801741	4 801741	0 096035	0.644661	4.15708	0			6.71
28			0 0	4.15708	4.15708	0.083142	0.572832	3.584248	0			6.89
29			0.0	3.584248	3.584248	0.071685	0.44256	3.141688	0			6.17
30			0.0	3.141688	3.141688	0.062834	0.41353	2.728158	0			6.58
31			0 0	2.728158	2.728158	0.054563	0.37926	2.348898	0			6.95
1	sep		0.0	2.348898	2.348898	0.046978	0	2.348898	0			

CHANNEL WATER BALANCE

WAD ALSIR

			Rain or TI	soil content		coefficient soil content/MAXTST	actual evaporation ETo* coeff		deep percolation			POTENTIAL EVAPOTRANSP RATI
1	mar		0 0	0	0							9 27
2			0 0	0	0	0	0	0	0			9 63
3			0	0	0	0	0	0	0			5 39
4			0 0	0	0	0	0	0	0			9 18
5			0 0	0	0	0	0	0	0			6 88
6			0	0	0	0	0	0	0			7 31
7			0 0	0	0	0	0	0	0			5 42
8			0 0	0	0	0	0	0	0			9 49
9			0	0	0	0	0	0	0			5 88
1			0 0	0	0	0	0	0	0			6 05
11			0 0	0	0	0	0	0	0			6 69
12			0	0	0	0	0	0	0			9 49
13			0 0	0	0	0	0	0	0			4 93
14			0	0	0	0	0	0	0			9 49
15			0 0	0	0	0	0	0	0			4 83
16			0	0	0	0	0	0	0			6 34
17			0 0	0	0	0	0	0	0			4 85
18			0 0	0	0	0	0	0	0			7 2
19			0	0	0	0	0	0	0			6 5
20			0	0	0	0	0	0	0			6 3
21				0	0	0	0	0	0			5 50
22			0	0	0	0	0	0	0			6 41
23			0	0	0	0	0	0	0			5 70
24			0	0	0	0	0	0	0			7 39
25				0	0	0	0	0	0			6 9
26			0 0	0	0	0	0	0	0			5 58
27			1 4	1 4	1 4	0 028	0 1591587	1 2408413	0			5 68
28			0 8	2 0408413	2 0408413	0 0408168	0 178356	1 8624853	0			4 37
29			4 6	6 4624853	6 4624853	0 1292497	0 6023073	5 860178	0			4 66
30		12 2	93 3	99 160178	50	1	5 6728629	44 327137	49 160178	22122 08	29496 107	9 67
1				44 327137	44 327137	0 8865427	4 5326379	39 794499	0			9
1	apr			39 794499	39 794499	0 79589	5 2585789	34 53592	0			6 8
2			1 5	36 03592	36 03592	0 7207184	3 611053	32 424867	0			5 01
3				32 424867	32 424867	0 6484973	2 8838955	29 540972	0			4 45
4				29 540972	29 540972	0 5908194	2 5880944	26 952877	0			4 38
			9 1	36 052877	36 052877	0 7210575	3 3319383	32 720939	0			4 62
6		14 8	1 1	183 72094	50	1	4 1589178	45 841082	133 72094	60174 423	80292 569	4 16
7		2 7	334	379 84108	50	1	4 6590678	45 340932	329 84108	148428 49	197904 66	1 68
8				45 340932	45 340932	0 9068186	4 6083821	40 73255	0			5 08
9				40 73255	40 73255	0 814651	3 3301447	37 402405	0			4 09
			2	37 602405	37 602405	0 7520481	3 6084436	33 993962	0			4 89
			5	34 493962	34 493962	0 6898792	3 3168712	31 177091	0			4 81
			1 6	32 777091	32 777091	0 6555418	3 1035492	29 673541	0			4 73
			5 2	34 873541	34 873541	0 6974708	2 6921711	32 18137	0			3 88
4			8 2	40 38137	40 38137	0 8076274	3 1282267	37 255144	0			3 87
		20	256 8	293 05514	50	1	3 0013572	46 998643	243 05514	109374 81	145833 09	3 60
6			8	47 798643	47 798643	0 9559729	3 6277307	44 170912	0			3 79
17			5 1	49 270912	49 270912	0 9854182	3 8973998	45 373512	0			3 86
8				45 373512	45 373512	0 9074702	3 6032412	41 770271	0			3 87
9			5	42 270271	42 270271	0 8454054	3 7794891	38 490782	0			4 47
20				38 490782	38 490782	0 7698156	3 1691679	35 321614	0			4 12
2				35 321614	35 321614	0 7064323	3 3088946	32 012719	0			4 68
22				32 12719	32 012719	0 6402544	4 1494659	27 863254	0			6 48
				27 863254	27 863254	0 5572651	3 0197563	24 843497	0			5 42
4				24 843497	24 843497	0 4968699	3 521914	21 321583	0			7 09
				21 521583	21 521583	0 4304317	2 1199211	19 401662	0			4 93
25				19 401662	19 401662	0 3880332	1 8220323	17 57873	0			4 70
2			5	22 57873	22 57873	0 4515746	2 2286725	20 350057	0			4 84
28				20 350057	20 350057	0 4070011	1 9340932	18 415364	0			4 75
			9	20 315364	20 315364	0 4063073	1 5434128	18 771951	0			3 80
3				18 771951	18 771951	0 375439	1 8116752	16 960279	0			4 89
	may			16 960276	16 960276	0 3392055	1 7115148	15 246762	0			5 05
2				1 46762	15 246762	0 3049352	2 1695712	13 077100	0			6 31
			6	14 677189	14 677189	0 2935438	1 [illegible]	12 82403	0			6 82
4				16 493	16 52493	0 3304[illegible]	2 [illegible]	14 270936	0			5 69
5			[illegible]	14 270936	14 270936	0 2854187	1 [illegible]	12 [illegible]	0			6 96
6		[illegible]	[illegible] 3	31 945548	31 945548	0 [illegible]911	4 510[illegible]	27 4[illegible]	0			5 93
-			[illegible]	27 434647	27 434647	0 54[illegible]20	3 [illegible]1	24 1[illegible]78	0			6 96
8				24 178978	24 178978	0 48[illegible]	2 [illegible]1	21 24[illegible]	0			4 47
9			[illegible]	21 249000	21 249000	0 4240[illegible]	2 1117448	19 1[illegible]	0			5 09
1			0	19 37264	19 137264	0 3827463	2 1781[illegible]	16 [illegible]911	0			3 94
			9	16 95411	16 95411	0 3301822	3 [illegible]17	13 [illegible]179	0			90
2			[illegible] 9	22 792179	22 792179	0 4558436	3 [illegible]	18 [illegible]	0			5 29
		[illegible]	42 0	[illegible]	50	1	6 [illegible]176	44 [illegible]	111 60139	[illegible]683	[illegible]831	5 65
14		28 4	428 8	473 41[illegible]	50	1	6 6618745	44 [illegible]	423 41[illegible]	19[illegible]	25[illegible] 39	4 49
15			[illegible]	44 [illegible]	44 [illegible]	0 [illegible]	3 [illegible]	40 [illegible]	0			4 79
16			[illegible]	45 [illegible]	45 [illegible]	0 [illegible]	4 [illegible]	41 [illegible]	0			5 33
7			[illegible]	4 [illegible]	41 [illegible]	0 [illegible]168	4 [illegible]	36 [illegible]	0			4 51
18			6 0	[illegible]	36 [illegible]	0 [illegible]	3 [illegible]	33 [illegible]	0			5 84
19			[illegible]	33 [illegible]	33 [illegible]	0 [illegible]	3 [illegible]	29 [illegible]	0			5 82
20			[illegible]	29 [illegible]	29 [illegible]	0 [illegible]471	3 [illegible]	26 [illegible]	0			5 38
21			[illegible]	26 [illegible]	26 [illegible]	0 [illegible]	2 [illegible]	23 [illegible]	0			5 41
22			[illegible]	23 [illegible]	23 [illegible]	0 [illegible]	2 [illegible]	20 [illegible]	0			6 35
23			[illegible]	20 [illegible]	20 [illegible]	0 [illegible]	2 [illegible]	18 [illegible]	0			5 09
24			[illegible]	[illegible]	8 [illegible]	0 [illegible]	1 [illegible]	18 [illegible]	0			5 31
25			[illegible]	16 [illegible]	6 [illegible]	0 [illegible]	1 [illegible]	14 [illegible]	0			5 85
26			[illegible]	14 [illegible]	4 [illegible]	0 [illegible]	1 [illegible]	12 [illegible]	0			6 38
-			[illegible]	2 [illegible]	2 [illegible]	0 [illegible]	1 [illegible]	11 [illegible]	0			6 41
28			[illegible]	[illegible]	1 [illegible]	0 [illegible]	1 [illegible]	8 [illegible]	0			8 23
29			[illegible]	9 [illegible]	9 [illegible]	0 [illegible]	1 [illegible]	8 [illegible]	0			[illegible]
30			[illegible]	8 [illegible]	8 [illegible]	0 [illegible]	0 [illegible]	[illegible]	0			6 52
31			[illegible]	7 [illegible]	7 [illegible]	0 [illegible]	0 [illegible]	6 [illegible]	0			

D-3

1	jun		0 0	6 3194363	6 3194363	0 1263887	0 7375583	5 581878	0			5 84
2			0 0	5 581878	5 581878	0 1116376	0 6292783	4 9525996	0			5 64
3			0 0	4 9525996	4 9525996	0 099052	0 6506463	4 3019533	0			6 57
4			0 0	4 3019533	4 3019533	0 0860391	0 6028652	3 6990881	0			7 01
5			1 0	4 6990881	4 6990881	0 0939818	0 6316827	4 0674054	0			6 72
6			0 0	4 0674054	4 0674054	0 0813481	0 4879378	3 5794676	0			6 00
7			0 0	3 5794676	3 5794676	0 0715894	0 4048608	3 1746068	0			5 66
8			0 0	3 1746068	3 1746068	0 0634921	0 3883343	2 7862725	0			6 12
9			0 0	2 7862725	2 7862725	0 0557255	0 4227264	2 3635461	0			7 59
10			0 0	2 3635461	2 3635461	0 0472709	0.2753657	2 0881804	0			5 83
11			0 0	2 0881804	2 0881804	0 0417636	0.2890956	1 7990848	0			6.92
12			0 0	1 7990848	1 7990848	0 0359817	0 250576	1 5485088	0			6 96
13			0	1 5485088	1 5485088	0 0309702	0 2064516	1 3420572	0			6 67
14			0 0	1 3420572	1 3420572	0 0268411	0 1703145	1 1717427	0			6 35
15			0 0	1 1717427	1 1717427	0 0234349	0 1609272	1 0108155	0			6.87
16			0	1 0108155	1 0108155	0 0202163	0 1742904	0 8365251	0			8 62
17			0 0	0 8365251	0 8365251	0 0167305	0 1251658	0 7113593	0			7 48
18			0 0	0 7113593	0 7113593	0 0142272	0 1044047	0 6069547	0			7 34
19			0	0 6069547	0 6069547	0 0121391	0 0943467	0 512608	0			7 77
20				0 512608	0 512608	0 0102522	0 079962	0 4326459	0			7 80
21			0	0 4326459	0 4326459	0 0086529	0 0640139	0 3686321	0			7.40
22			0	0.3686321	0 3686321	0 0073726	0 0409005	0.3277315	0			5 55
23			0	0.3277315	0 3277315	0 0065546	0 0382946	0.2894369	0			5 84
24			0 0	0.2894369	0.2894369	0 0057887	0 038049	0 2513879	0			6 57
25			0 0	0 2513879	0.2513879	0 0050278	0 0307922	0.2205957	0			6 12
26			0	0.2205957	0 2205957	0 0044119	0 0375102	0 1830854	0			8 50
27			0	0 1830854	0 1830854	0 0036617	0 0325468	0 1505386	0			8 89
28			0 0	0 1505386	0 1505386	0 0030108	0 0234211	0 1271175	0			7 78
29			0	0 1271175	0 1271175	0 0025423	0 0165176	0 1105999	0			6 50
30			0 0	0 1105999	0 1105999	0 002212	0 014738	0 0958619	0			6 66
1	jul		0 0	0 0958619	0 0958619	0 0019172	0 0129309	0 082931	0			6 74
2			0 0	0 082931	0 082931	0 0016586	0 0102548	0 0726762	0			6 18
3			0	0 0726762	0 0726762	0 0014535	0 0083778	0 0642984	0			5 76
4			0	0 0642984	0 0642984	0 001286	0 0121734	0 052125	0			9 47
5				0 052125	0 052125	0 0010425	0 0091466	0 0429784	0			8 77
6				0 0429784	0 0429784	0 0008596	0 006145	0 0368334	0			7 15
7				0 0368334	0 0368334	0 0007367	0 006811	0 0300223	0			9.25
8				0 0300223	0 0300223	0 0006004	0 0048743	0 0251481	0			8 12
9				0 0251481	0 0251481	0 000503	0 0035955	0 0215526	0			7 15
1				0 0215526	0 0215526	0 0004311	0 0035184	0 0180342	0			8 16
11				0 0180342	0 0180342	0 0003607	0 0025704	0 0154638	0			7 13
12			0	0 0154638	0 0154638	0 0003093	0 0022651	0 0131986	0			7 32
13			0	0 0131986	0 131986	0 000264	0 0020161	0 0111825	0			7 64
14				0 0111825	0 0111825	0 0002237	0 0015316	0 0096509	0			6 85
15				0 0096509	0096509	0 000193	0 0013898	0 0082611	0			7.20
16				0 0082611	0 0082611	0 0001652	0 0010386	0 0072225	0			6.29
17				0 0072225	0 0072225	0 0001445	0 0011572	0 0060653	0			8 01
18				0 0060653	0 0060653	0 0001213	0 0009641	0 0051012	0			7.95
19				0 0051012	0 0051012	0 000102	0 0006025	0 0044987	0			5.91
20			0	0 0044987	0 0044987	8.997E-05	0 0005181	0 0039806	0			5 76
21			1 8	1 8039806	1 8039806	0 0360796	0 3047153	1 4992653	0			8 45
22			0	1 4992653	1 4992653	0 0299853	0.2355592	1.2637061	0			7 86
23			0	1.2637061	1.2637061	0 0252741	0.2593135	1 0043926	0			10.26
24		1 8	2.5	3 5043926	3.5043926	0 0700879	0 5565483	2 9478443	0			7 94
25			0 0	2 9478443	2 9478443	0 0589569	0 3929735	2 5548708	0			6 67
26			0 0	2.5548708	2.5548708	0 0510974	0 4415877	2 1132832	0			8 64
27			0	2 1132832	2 1132832	0 0422657	0 3609732	1 75231	0			8.54
28			0	1 75231	1 75231	0 0350462	0.211783	1 540527	0			6 04
29				1 540527	1 540527	0 0308105	0.2299185	1 3106085	0			7 46
30				1 3106085	1 3106085	0 0262122	0 1938422	1 1167663	0			7 40
31				1 1167663	1 1167663	0 0223353	0 1438202	0 9729461	0			6 44
1	aug			0 9729461	0 9729461	0 0194589	0 1155424	0 8574037	0			5.94
2				8574037	0 8574037	0 0171481	0 1242596	0 7331441	0			7 25
3				0 7331441	0 7331441	0 0146629	0 1414274	0.5917167	0			9.65
4			0	0 5917167	0 5917167	0 0118343	0 0843356	0 5073812	0			7 13
5			0	.5073812	0 5073812	0 0101476	0 0775158	0 4298653	0			7 64
6			0	0 4298653	0 4298653	0 0085973	0 060037	0 3698284	0			6 98
7			0	0 3698284	0 3698284	0 0073966	0 0658976	0 3039307	0			8 91
8			0 0	0.3039307	0 3039307	0 0060786	0 0323907	0.27154	0			5 33
9			0 0	0.27154	0 27154	0 0054308	0 0303497	0.2411904	0			5.59
10		21 6	173 9	174 14119	50	1	7 1917944	42 808206	124 14119	55863 536	74484 714	7 19
11		9 7	354 8	397 60821	50	1	5 8987352	44 101265	347 60821	156423 69	208564 92	5 90
12			0	44 101265	44 101265	0 8820253	6 3861148	37 71515	0			7.24
13			0 0	37 71515	37 71515	0 754303	5 0808708	32 634279	0			6.74
14			0 5	33 134279	33 134279	0 6626856	5.5657164	27 568563	0			8 40
15			0 0	27 568563	27 568563	0 5513713	3 6950376	23.873525	0			6.70
16			0 0	23 873525	23 873525	0 4774705	3 6121996	20.261326	0			7.57
17			0 0	20 261326	20.261326	0 4052265	2 6425431	17 618783	0			6 52
18			0 0	17 618783	17 618783	0 3523757	1 9250703	15 693712	0			5 46
19			0 0	15 693712	15 693712	0 3138742	1 9534139	13 740298	0			6.22
20			0 0	13 740298	13 740298	0.274806	2.2054269	11.534871	0			8 03
21			0 0	11.534871	11 534871	0.2306974	1 3429704	10.191901	0			5 82
22			0 0	10 191901	10 191901	0.203838	1 3729429	8 8189582	0			6.74
23			0 0	8 8189582	8 8189582	0 1763792	1.5286358	7.2903224	0			8.67
24			0 0	7.2903224	7 2903224	0 1458064	0 9048319	6 3854905	0			6.21
25			0 0	6 3854905	6 3854905	0 1277098	0 9254541	5.4600365	0			7.25
26			0 0	5 4600365	5 4600365	0 1092007	0 8125832	4.6474533	0			7.44
27			0 0	4 6474533	4 6474533	0 0929491	0 6239468	4 0235065	0			6 71
28			0 0	4 0235065	4 0235065	0 0804701	0 554426	3 4690805	0			6 89
29			0 0	3 4690805	3 4690805	0 0693816	0 4283398	3 0407407	0			6.17
30			0 0	3 0407407	3 0407407	0 0608148	0 4002423	2.6404984	0			6 58
31			0 0	2 6404984	2 6404984	0 05281	0 3670739	2.2734245	0			6 95
1	sep		0 0	2.2734245	2.2734245	0 0454685	0	2.2734245	0			

Infromation about the tributaries

	Garadha	Alhijra	Bahman	Ratich	Huwglaha
Area km2	20	22	11	18.5	75.5
soil1	9.1	11.3	4.8	8	13.4
soil2	7.1	9.9	5.5	7.3	53.3
soil5	3.8	0.8	0.7	3.2	8.8
soil6	0	0	0	0	0

Volume of floods
estimated from rainfall-runoff

in CUM	Garadha	Alhijra	Bahman	Ratich	Huwglaha
30.3	1519	7371	2961	1369	18.3
7.4	49044	76243	35746	45312	136719
15.4	27831	48508	22309	25645	66216
14.5	120205	167312	79989	111087	373177
8.8	14078	33373	14643	12824	17741
9.8	46670	71816	33732	27171	134237 ,

	Modelled area
area	182.7
soil1	80.6
soil2	73.1
soil5	22.3
soil6	6.7

Volume of floods
used in MODFLOW

Garadha	Alhijra	Bahman	Ratich	Huwglah
1800	9000	3600	1800	0
48960	75600	36000	45360	136800
28080	48060	22140	25380	64800
118800	156240	72000	108000	446400

Their distribution over time
See hydrographs

Wadi Dhar input parameters for Modelled area

	aquifer	aquifer		Stream information					conductance		
Column	top	base	+2000 masl	44 cells	row	column	Segment	Reach		bottom	top
1	285 7	267			11	2	1	1	0 013	275 2	277 2
2	285	266			10	3	1	2	0 013	274 5	276 5
3	284 3	265			9	4	1	3	0 013	273 8	275 8
4	283 6	264			8	5	1	4	0 013	273 1	275 1
5	282 9	263			7	6	1	5	0 013	272 4	274 4
6	282 2	262			7	7	1	6	0 013	271 7	273 7
7	281 5	261			7	8	1	7	0 013	271	273
8	280 8	260			7	9	1	8	0 013	270 3	272 3
9	280 1	259			7	10	1	9	0 013	269 6	271 6
1	279 4	258			6	11	1	10	0 013	268 9	270 9
11	278 7	257			2	11	2	1	0 013	270 3	272 3
12	278	256			3	12	2	2	0 013	269 6	271 6
13	277 3	255			4	12	2	3	0 013	268 9	270 9
14	276 6	254			5	12	3	1	0 011	268 2	270 2
15	275 9	253			5	13	3	2	0 011	267 5	269 5
16	275 2	252			5	14	3	3	0 011	266 8	268 8
17	274 5	251			5	15	3	4	0 011	266 1	268 1
18	273 8	250			5	16	3	5	0 011	265 4	267 4
19	273 1	249			6	17	3	6	0 011	264 7	266 7
2	272 4	48			6	18	3	7	0 011	264	266
21	271 7	247			6	19	3	8	0 011	263 3	265 3
22	271	246			7	20	3	9	0 011	262 6	264 6
23	27 3	245			7	21	3	10	0 011	261 9	263 9
24	269 6	244			7	22	3	11	0 011	261 5	263.5
25	268 9	243			7	23	3	12	0 011	261 1	263 1
26	268 2	242			7	24	3	13	0 011	260 7	262 7
27	267 5	241			7	25	3	14	0 011	260 3	262 3
28	266 8	240			7	26	3	15	0 011	259 9	261 9
29	266 1	239			7	27	3	16	0 011	259 5	261 5
30	265 4	238			7	28	3	17	0 011	259 1	261 1
31	264 7	237			7	29	3	18	0 011	258 7	260 7
32	264	236			7	30	3	19	0 011	258 3	260 3
33	263 3	236			7	31	3	20	0 011	257 9	259 9
34	262 6	234			7	32	3	21	0 011	257 4	259 4
35	261 9	233			7	33	3	22	0 011	257	259
36	261 2	232			7	34	3	23	0 011	256 6	258 6
37	260 5	231			7	35	3	24	0 011	256 2	258 2
38	259 8	230			7	36	3	25	0 011	255 8	257 8
39	259 1	229			8	37	3	26	0 011	255 4	257 4
40	258 4	228			9	38	3	27	0 011	255	257
41	257 7	227			10	39	3	28	0 011	254 6	256 6
42	257	200			11	40	3	29	0 011	254.2	256 2
					12	41	3	30	0 011	253 8	255 8
					13	42	3	31	0 011	253 4	255 4

number of row	15
number of column	42
number of layer	1
Total cell	630
total active	344
inactive	45

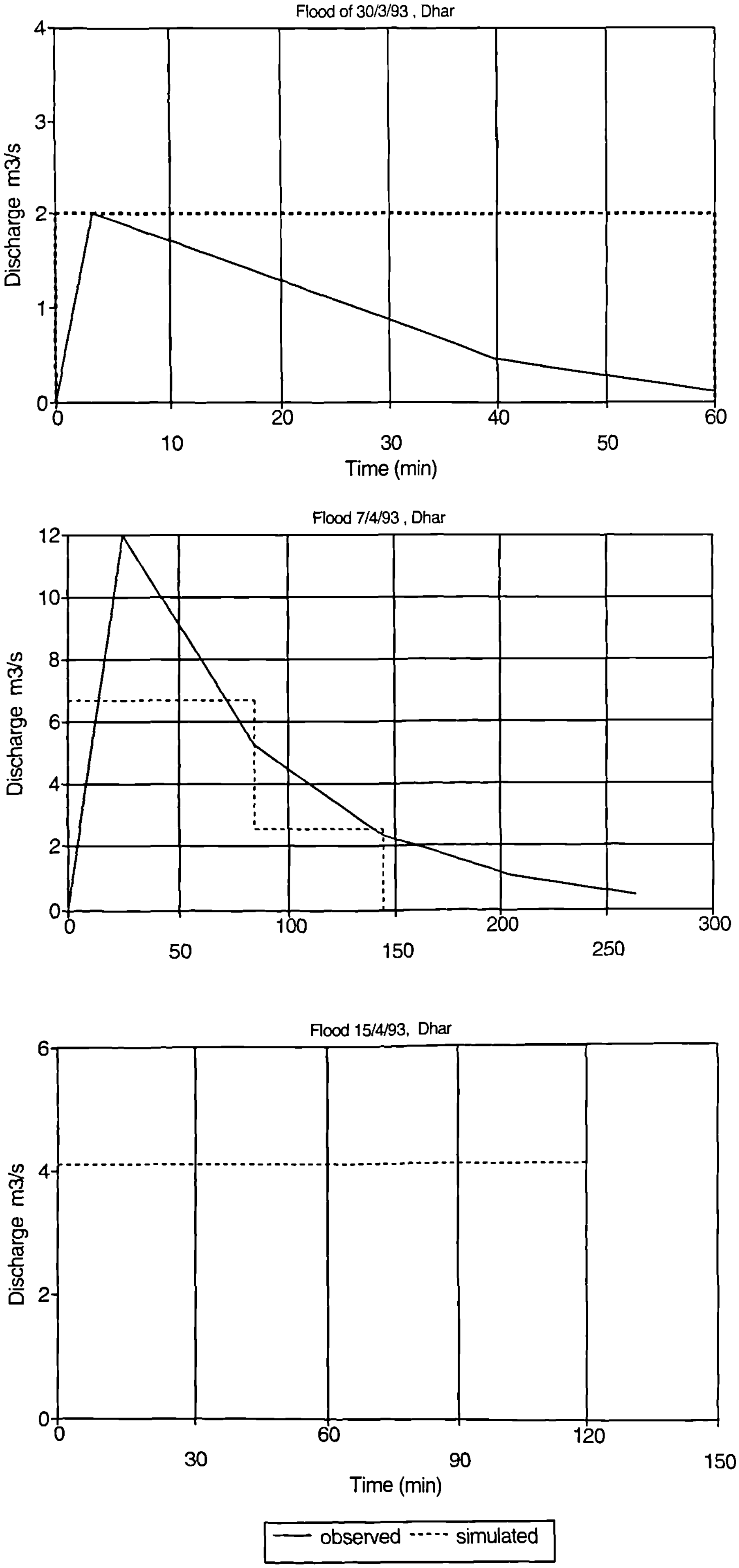
Kx=Ky=Kz		1E-05
Sy	11	

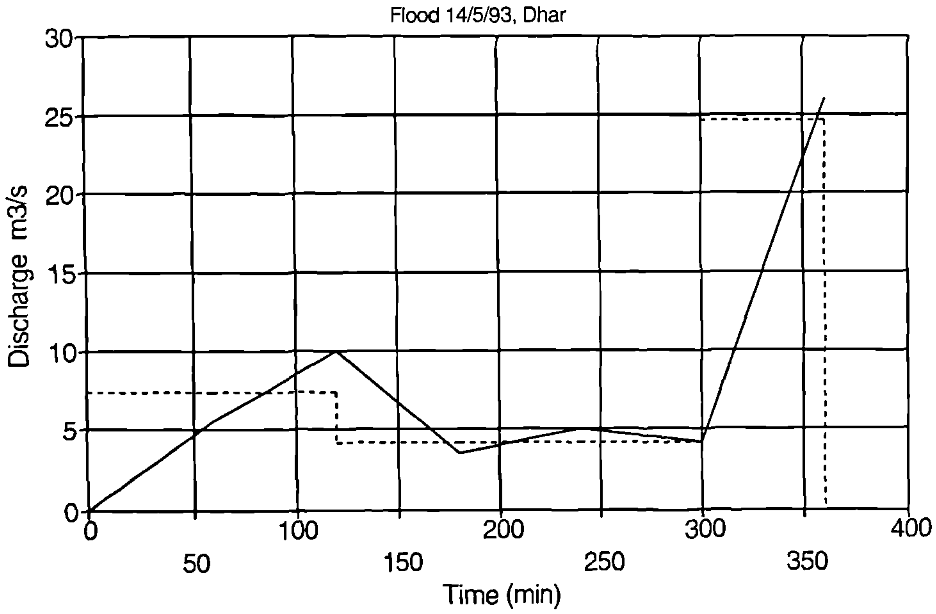
general head Boundary

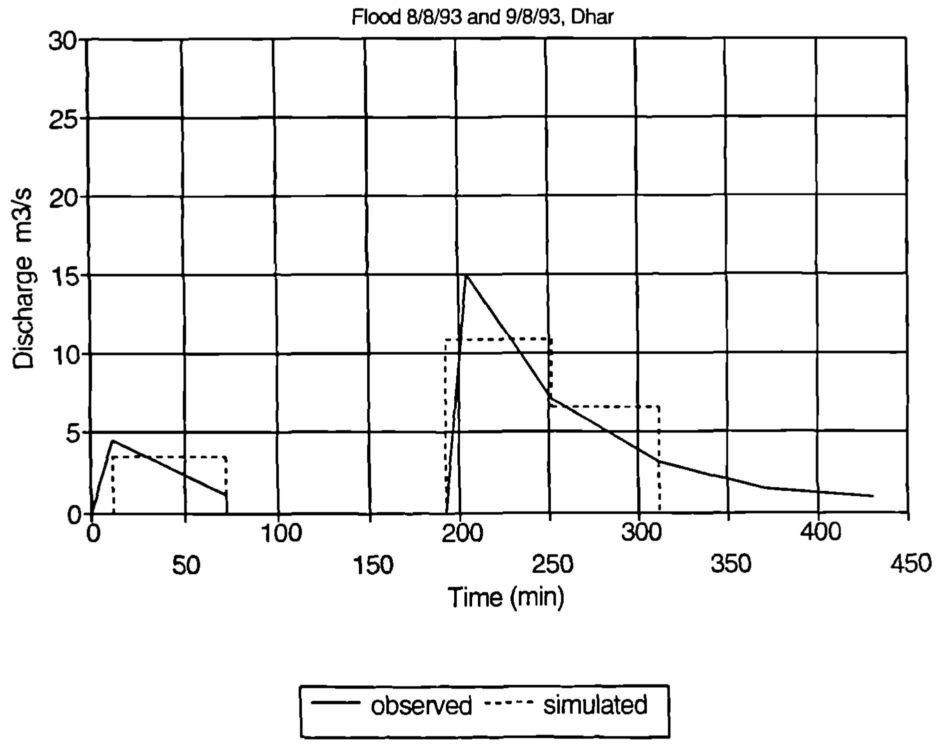
number	row	column	head	conducatance
1	6	42	224	0 0028
2	7	42	224	0 0028
3	8	42	224	0 0028
4	9	42	224	0 0028
5	1	42	224	0 0028
6	11	42	224	0 0028
7	12	42	224	0 0028
8	13	42	224	0 0028
9	14	42	224	0 0028

Wells

1	7	1	2.8E-05	
2	8	1	2.8E-05	
3	9	1	2.8E-05	
4	10	1	2.8E-05	
5	11	1	2.8E-05	
6	12	1	2.8E-05	
7	13	1	2.8E-05	
8	1	11	2.8E-05	
9	1	12	2.8E-05	
			1389600 - 3801600	4320000 - 7862400
10	6	6	-0 001	-0 02
11	5	8	-0 001	-0 02
12	8	15	-0 001	-0 02
13	5	21	-0 001	-0 02
14	8	25	0	-0 02


Flood of 30/3/93 , Dhar
Discharge m3/s
Time (min)
Flood 7/4/93 , Dhar
Discharge m3/s
Flood 15/4/93, Dhar
Discharge m3/s
Time (min)
observed
simulated


Flood 14/5/93, Dhar
Discharge m3/s
Time (min)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400


Flood 8/8/93 and 9/8/93, Dhar
Discharge m3/s
Time (min)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
450
observed
simulated

Wadi alSir input parameters

column	aquifer surface	aquifer base
1	2345.7	2282.5
2	2342.8	2279
3	2340	2275.5
4	2337.2	2272
5	2334.34	2268.5
6	2331.49	2265
7	2328.6	2261.5
8	2325.8	2258
9	2322.9	2254.5
10	2320	2251
11	2317.8	2247.5
12	2315.6	2244
13	2313.4	2240.5
14	2311.2	2237
15	2309	2233.5
16	2306.8	2230
17	2304.6	2226.5
18	2302.4	2223
19	2300	2219.5
20	2297.2	2216
21	2294.3	2212.5
22	2291.5	2209
23	2288.6	2205.5
24	2285.8	2202
25	2282.9	2198.5
26	2280	2195
27	2277.2	2191.5
28	2274.3	2188
29	2271.5	2184.5
30	2268.6	2181
31	2265.8	2177.5
32	2262.9	2174
33	2260	2170.5
34	2258.8	2167
35	2257.5	2163.5

number of row	28
number of columns	35
number of layer	1
total cell	980
total active	398
percent active	59

Three Kx=Ky=Kz zones

	m/s	
1	6E-06	Rest of model area
2	8E-06	along wadi channel
3	2.8E-06	column 7 to 15

Two specific yield zones

1	0.08	rest of modelled area
2	0.055	column 7 to 15

Recharge two zones

	m/s		Area
1	1.14E-12	Rest of modelled area	39690000
2	1.14E-09	the boundary of active cells	5156000

General head boundary = 10 cells

	row	column	head	conductance
1	12	35	202	0.017
2	13	35	202	0.017
3	14	35	202	0.017
4	15	35	202	0.017
5	16	35	202	0.017
6	17	35	202	0.017
7	18	35	202	0.017
8	19	35	202	0.017
9	20	35	202	0.017
10	21	35	202	0.017

total wells 23

well no	row	column	discharge m3/sec
1	11	1	6E-05
2	12	1	6E-05
3	13	1	6E-05
4	14	1	6E-05
5	15	1	6E-05
6	19	17	-0.00044
7	20	21	-0.00012
8	20	27	-0.00077
9	15	26	-0.00034
10	15	25	-0.0005
11	18	31	-0.00018
12	14	32	-0.0006
13	20	16	-0.00107
14	9	30	-0.0005
15	15	21	-0.00067
16	14	10	-0.00048
17	12	9	-0.00061
18	17	21	-0.0003
19	19	24	-0.0005
20	20	23	-0.0005
21	12	7	-0.0005
22	13	7	-0.0005
23	21	19	-0.00024

stream information

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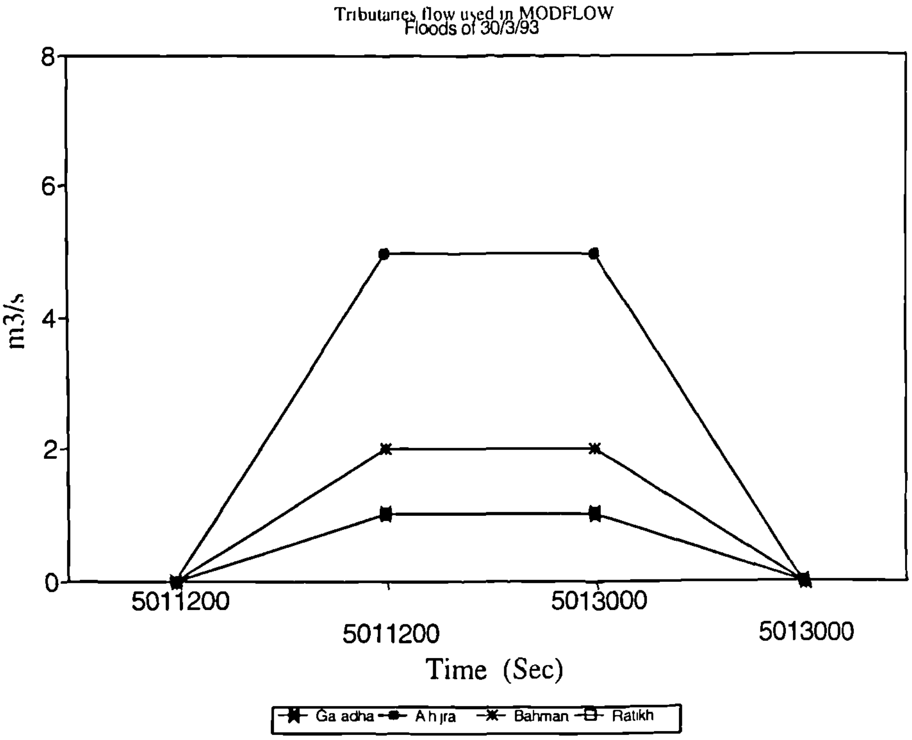
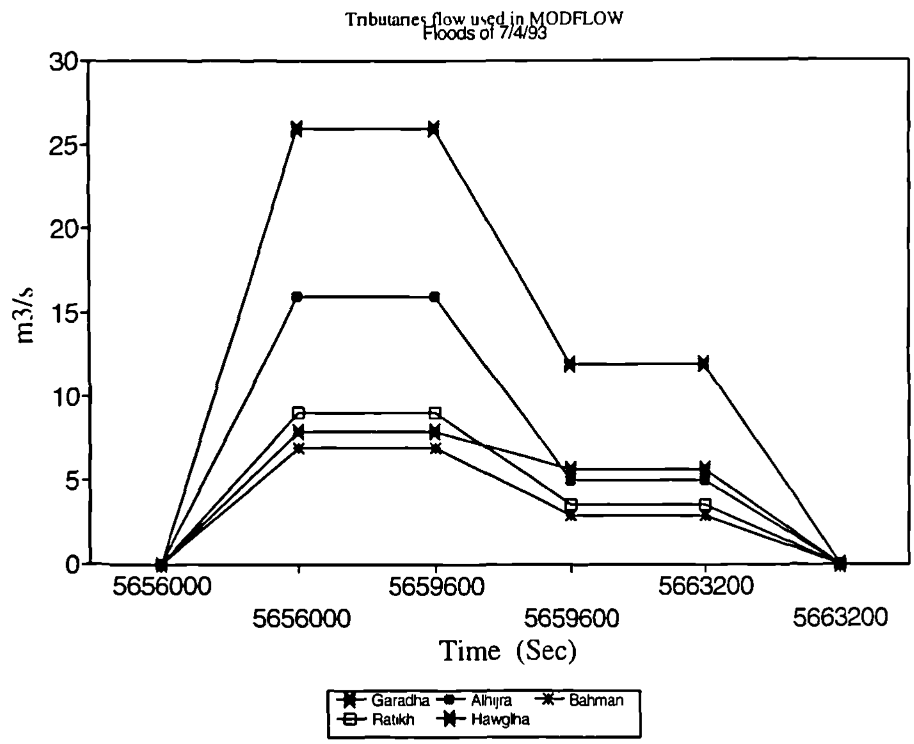
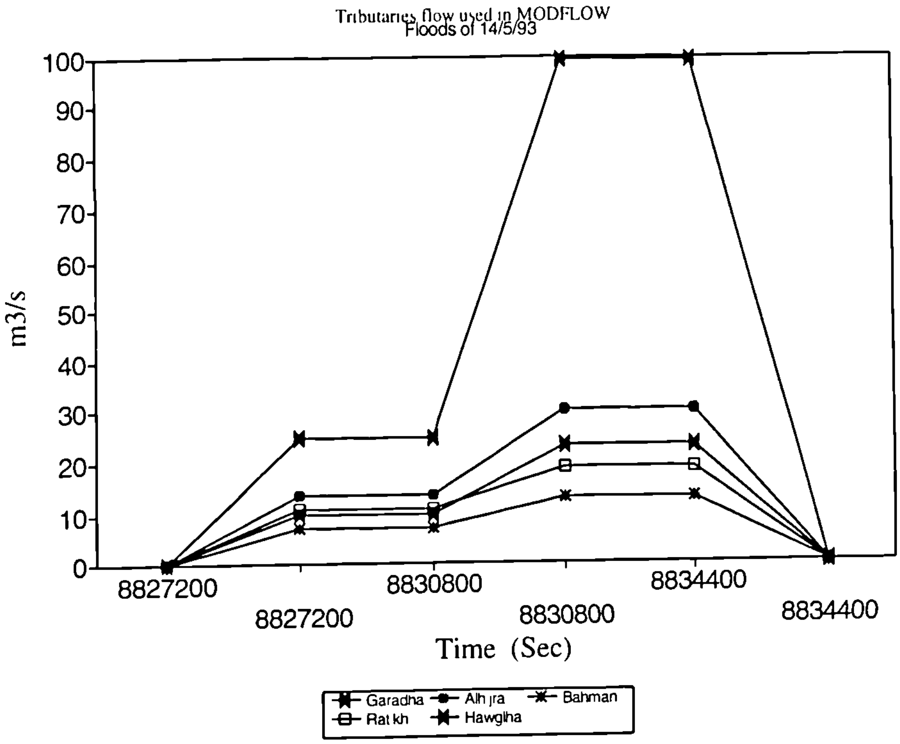
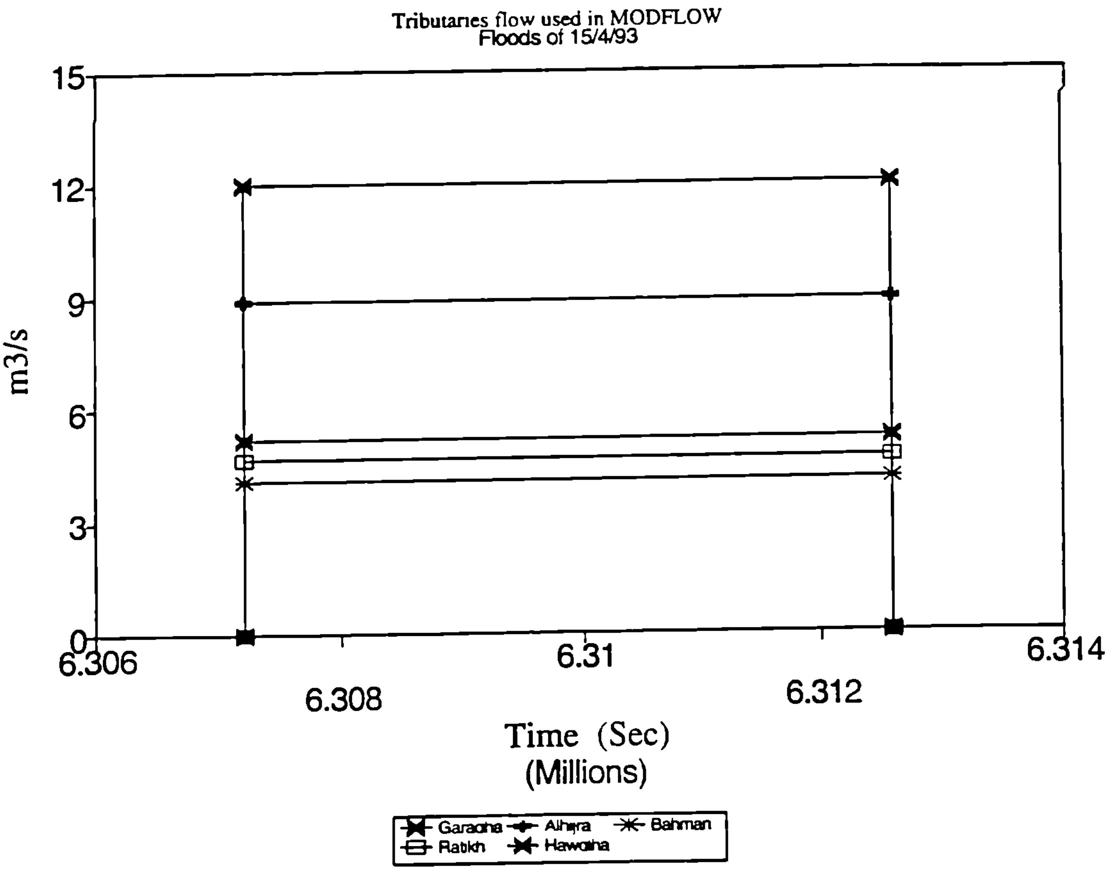
row	column	segment	reach	conductan	wadi botto	wadi top	width	slope	n
14	2	1	1	0.2	316	318	20	0.011	0.03
14	3	1	2	0.2	315	317	20	0.011	0.03
14	4	1	3	0.2	314	316	20	0.011	0.03
14	5	1	4	0.2	313.8	315.8	20	0.011	0.03
9	4	2	1	0.2	316	318	20	0.011	0.03
10	4	2	2	0.2	315	317	20	0.011	0.03
11	5	2	3	0.2	314	316	20	0.011	0.03
12	6	2	4	0.2	313.6	315.6	20	0.011	0.03
13	6	2	5	0.1	313.6	315.6	20	0.011	0.03
14	6	3	1	0.2	313	315	20	0.011	0.03
14	7	3	2	0.2	309.12	311.12	20	0.011	0.03
23	3	4	1	0.2	338	340	20	0.011	0.03
23	4	4	2	0.2	335.2	337.2	20	0.011	0.03
22	5	4	3	0.2	332.4	334.4	20	0.011	0.03
21	6	4	4	0.1	330.9	332.9	20	0.011	0.03
20	6	4	5	0.1	329.5	331.5	20	0.011	0.03
19	6	4	6	0.1	326.6	328.6	20	0.011	0.03
18	6	4	7	0.1	323.8	325.8	20	0.011	0.03
17	6	4	8	0.1	320.9	322.9	20	0.011	0.03
16	7	4	9	0.2	314	316	20	0.011	0.03
15	8	5	1	0.2	306.9	308.9	20	0.011	0.03
16	9	5	2	0.2	304.7	306.7	20	0.011	0.03
17	10	5	3	0.2	302.5	304.5	20	0.011	0.03
18	11	5	4	0.2	300.2	302.2	20	0.011	0.03
17	12	5	5	0.2	298	300	20	0.011	0.03
18	13	5	6	0.2	295.14	297.14	20	0.011	0.03
19	14	5	7	0.2	292.3	294.3	20	0.011	0.03
20	15	5	8	0.2	289.4	291.4	20	0.011	0.03
21	16	5	9	0.2	286.6	288.6	20	0.011	0.03
20	17	5	10	0.2	283.7	285.7	20	0.011	0.03
27	19	6	1	0.2	292.2	294.2	20	0.011	0.03
26	19	6	2	0.2	289.6	291.6	20	0.011	0.03
25	18	6	3	0.2	287.9	289.9	20	0.011	0.03
24	18	6	4	0.2	286.5	288	20	0.011	0.03
23	18	6	5	0.2	285.1	287.1	20	0.011	0.03
22	18	6	6	0.2	283.7	285.7	20	0.011	0.03
21	18	6	7	0.2	282.3	284.3	20	0.011	0.03
20	18	7	1	0.2	280.9	282.9	20	0.011	0.03
19	19	7	2	0.2	278	280	20	0.011	0.03
19	20	7	3	0.2	275.14	277.14	20	0.011	0.03
18	21	7	4	0.2	272.29	274.29	20	0.011	0.03
17	22	7	5	0.2	269.4	271.4	20	0.011	0.03
17	23	7	6	0.2	266.6	268.6	20	0.011	0.03
16	24	7	7	0.2	263.7	265.7	20	0.011	0.03
16	25	7	8	0.2	260.86	262.86	20	0.011	0.03
17	26	7	9	0.2	258	260	20	0.011	0.03
18	27	7	10	0.2	256.75	258.75	20	0.011	0.03
19	28	7	11	0.2	255.5	257.5	20	0.011	0.03
18	29	7	12	0.2	254.25	256.25	20	0.011	0.03
17	30	7	13	0.2	253	255	20	0.011	0.03
16	31	7	14	0.2	251.75	253.75	20	0.011	0.03
15	32	7	15	0.2	250.5	252.5	20	0.011	0.03
4	26	8	1	0.2	272	274	20	0.011	0.03
5	27	8	2	0.2	269.5	271.5	20	0.011	0.03
6	28	8	3	0.2	267	269	20	0.011	0.03
7	29	8	4	0.2	264.5	266.5	20	0.011	0.03
8	30	8	5	0.2	262	264	20	0.011	0.03
9	31	8	6	0.2	259.5	261.5	20	0.011	0.03
10	31	8	7	0.2	257	259	20	0.011	0.03
11	32	8	8	0.2	254.5	256.5	20	0.011	0.03
12	33	8	9	0.2	252	254	20	0.011	0.03
13	33	8	10	0.2	250.5	252.5	20	0.011	0.03
14	33	9	1	0.2	249.3	251.3	20	0.011	0.03
14	34	9	2	0.2	248	250	20	0.011	0.03


Tributaries flow used in MODFLOW
Floods of 30/3/93
m3/s
Time (Sec)
5011200
5013000
Ga adha
A h jra
Bahman
Ratikh


Tributaries flow used in MODFLOW
Floods of 7/4/93
m3/s
Time (Sec)
5656000
5659600
5663200
Garadha
Alhijra
Bahman
Ratikh
Hawgiha


Tributaries flow used in MODFLOW
Floods of 14/5/93
m3/s
100
90
80
70
60
50
40
30
20
10
0
8827200
8827200
8830800
8830800
8834400
8834400
Time (Sec)
Garadha
Alhijra
Bahman
Ratikh
Hawgiha


Tributaries flow used in MODFLOW
Floods of 15/4/93
m3/s
15
12
9
6
3
0
6.306
6.308
6.31
6.312
6.314
Time (Sec)
(Millions)
Garadha
Alhijra
Bahman
Ratikh
Hawgiha

	Region A	395.1	km2		Region B	774.4	km2		Region C	690.5	km2	
		Qup	Qtot	recharge		Qup	Qtot	recharge		Qup	Qtot	
1974		8957774	8026848	1077280		32411127	14138197	17725674		12586619	1185249	10828443
1975		18902629	17332218	1946862		52948391	25422069	26851139		26144518	3130892	21914284
1976		2775853	2533877	293130.5		8133645	3539118	4459209		2747933	197131.9	2422992
1977		26364359	24777474	2182370		84189716	39238420	43811195		49395561	9364606	38273456
1978		2260234	1911331	367641.2		5390306	1893216	3355720		835503.8	0	780347.5
1979		152913.4	108481.7	41835.03		317733.5	26540.21	273977.8		0	0	0
1980		6103179	5470172	732541.5		16376272	7137905	8959915		4647889	69148.91	4336016
1981		5021605	4479624	620705		13310270	5539553	7522011		3377262	59278.35	3130358
1982		17446558	16495246	1342011		57420626	25998761	30578977		35609491	7804600	26621962
1983		27725422	26174021	2190742		84063505	41547001	41573021		53643097	10966825	40841177
1984		5616517	5137344	587300.1		16409214	7615930	8561482		9159948	959633.9	7807562
1985		5540313	5115319	527466.3		17638958	7824631	9526089		9342342	1777168	7227042
1986		11988350	11161790	1071634		37952667	16677838	20666965		19443252	3636068	15104661
1987		966664.4	808010.7	164471.5		2267078	701603.4	1494095		109585.2	0	97842.08
1988		4900166	4416711	563335.6		14340701	6000173	8075178		5844044	665464.7	4923491
1989		1276618	1021816	257719.6		3174142	1092193	1996346		1417541	0	1333057
1990		519990.8	355591.6	148815.3		1307951	200616.2	1040517		303573.1	0	277862.3
1991		50.51494	0	0		0.965166	0	0		0	0	0
1992		3727903	3094708	656392.3		9038886	3096231	5702729		2479453	0	2331637
1993		7669985	6955311	850313.5		22879635	10180962	12328450		11603402	1749562	9391470
Average		7895854	7268795	781128.4		23978541	10893548	12725134		12434551	2078281	9882183

	Alsir	198.7	km2	Alsfal	217.1 km2		AlRawna	76.6	km2
	Qup	Qtot		Qup	Qtot		Qup	Qtot	
1974	3558473	2359352	1849916	2966958	1413227	2077955	1177704	724566.6	640369.5
1975	7987976	5368846	4171461	6632070	3172435	4762434	2647126	1649569	1469716
1976	3942341	3130286	1414385	3111420	2105721	1576153	1291115	1002084	467309.8
1977	23348552	20699239	5251366	21772267	18044148	6406227	8244129	7377367	1621653
1978	1041478	445566.9	786635.8	589910.3	39379.38	535845.5	295233.3	84194.4	232191.6
1979	1404559	826375.2	878152.4	929287.8	247726	800667.8	427998	207420.7	294833.6
1980	2060483	1519836	876364.1	1390534	781128	852241.8	641765.5	447260.6	286753.1
1981	8624735	6893119	2988643	7047493	4814734	3386892	2873807	2250064	992961.1
1982	8574802	6771115	3087802	7224026	4835886	3547056	2868122	2210526	1036775
1983	11240733	8867681	4265657	10065452	6584966	5471991	3879905	2977321	1529277
1984	5032626	4429119	1230780	4587789	3714230	1610497	1744777	1547341	401620.8
1985	1606278	811961.5	1098063	1201622	315277.3	1023351	504623.7	212440.8	357195.1
1986	6817075	5510379	2336575	5712810	3990898	2811341	2278760	1814711	791694.9
1987	1238454	550053.9	892040.2	793075.8	115031.6	701402.4	364728.5	120429.6	269247.2
1988	2271756	1495857	1164377	1762381	833178	1196574	726920.9	439043.6	388319.9
1989	2433676	1587707	1347537	2051642	902039.1	1568236	817458.8	487836.1	486257.7
1990	398066.7	127061	313382.9	274343.6	18796.88	248072.1	116501.1	24230.73	91941.46
1991	84836.34	1240.05	69857.91	23038.83	0	13810.12	16554.56	0	6682.648
1992	6662623	4698663	3227513	5594756	2866398	3820729	2212668	1456953	1147673
1993	3630173	2351085	1991815	3049427	1367448	2236131	1216132	722292.4	705375
	5097985	3922227	1962116	4339015	2808132	2232380	1717301	1287783	660892.3
	25.65669	19.73944	9.874767	19.98625	12.93474	10.28273	22.41908	16.81178	8.627837

	Rujam	46.2	km2	Al Mhajir	80.2	km2	Dhar	321.9	km2
	Qup	Qtot		Qup	Qtot		Qup	Qtot	
1974	567844.5	336093.9	309919.8	5917230	5774171	552665.2	4571139	708904.2	4132465
1975	1280350	759573.1	726035.8	4050575	2741063	2032062	21702010	7886950	16803517
1976	634422.8	485437.1	233682.4	576549.2	386521.3	286754.3	4479626	959606.2	3896960
1977	4569855	4023929	989292.2	5484063	4170067	2171034	28961394	18325673	14201098
1978	98075.84	15945.11	69787.58	508276.6	223524.3	365738.2	1504709	0	1401687
1979	171914.6	68717.98	118525.3	37130.37	4781.793	30248.93	2474243	213297.9	2309094
1980	279448.3	189879.9	122508.8	1305792	789446	729516.1	5095986	854659	4562330
1981	1437888	1108039	507652.7	1059544	623127.1	618342.5	8875350	2331304	7634126
1982	1457208	1102921	533238.9	3533752	2778594	1214718	15938797	8559099	8580278
1983	2041075	1512724	856813.4	5696271	4427317	2156622	32663873	26824379	12111656
1984	958471	828752.1	252419.1	1215192	819189.4	615692.1	3929017	1050300	3349817
1985	213922.7	82019.44	143520.8	1176628	835292.7	491803.9	2615708	89464.08	2455288
1986	1164466	909791.5	427362.3	2458822	1805419	1015238	2130588	16041.5	1992373
1987	132118.5	33919.58	88372.71	212437.9	85684.81	155714	790203.5	1086.577	740209.8
1988	334572.1	196425.5	170327.9	1061248	662779.8	557941.7	656777.1	0	606449.7
1989	395350.3	220313.1	242201.1	337491.1	122935.7	260103.1	4856523	2185910	3450755
1990	42688.52	6183.776	28110.76	157567.7	26226.4	124871.4	441246.3	0	405460.8
1991	1623.001	0	0	1735.312	0	0	2533673	47768.64	2378560
1992	1090850	680784.1	585843.2	871728.6	359904.8	626494.5	7913770	1119846	7182524
1993	586460.4	330172.9	341122.8	1683745	1094131	853891.3	8102301	2601941	6307141
Average	872930.3	644581.1	337336.9	1867289	1386509	742972.5	8011847	3688812	5225089
	18.8946	13.95197	7.301664	23.28291	17.28814	9.263997	24.88924	11.4595	16.23203

	Hamdan	29.7	km2	Akhwar	129.3	km2	Gabir	45.4	km2
	Qup	Qtot		Qup	Qtot		Qup	Qtot	
1974	612506.4	329904.7	347156.8	1763535	856470.3	1195100	359439.9	175741.1	219421.2
1975	2691547	1763017	1296393	3942563	1927850	2750792	2262514	1535983	990142.4
1976	621924.3	326679.1	343837.9	1828554	1273112	861779.1	360881.3	205084.6	172160
1977	3771040	3053217	1104027	12639468	10877687	2978135	3580851	3219236	712755.8
1978	252134.3	68643.66	182678.9	373101.4	26257.7	330459.4	80150.43	888.6272	59709.09
1979	339517.2	151077	224728.1	568215.5	154720.2	480904.2	184836.6	58604.77	135150.8
1980	680558.6	359013.8	388731.6	840116.4	482704.3	490468.6	417606.9	201620.3	251143.5
1981	1252441	862794.1	531572.7	4150826	2919591	1836788	783598.9	542409.7	323610.7
1982	2096410	1630868	672587.8	4227527	2908209	1924986	1784232	1530158	426989.4
1983	4367983	4000549	724711.1	5897072	3985781	3007283	4368283	4489699	552566.7
1984	492199.3	274237.9	271206.2	2647424	2228282	789543.9	373146.3	220277.5	201705.5
1985	348753.2	136884.1	234210.5	732367.4	194133.1	610639.5	172774.5	42669.69	131416.8
1986	316198.4	105126.9	214766.1	3337761	2400726	1521557	43838.43	6021.614	92105.92
1987	131977.6	38666.41	88429.34	495223.1	71095.63	425915	43838.43	6021.614	32278.94
1988	120657.7	23857.93	89199.22	1047686	500667.7	689632.3	26896.04	0	14132.3
1989	588035.3	417194.8	234033.7	1227400	553794.7	916125.2	521052.2	402295.2	156393.3
1990	97196.65	14244.85	68085.42	170870	11661.61	149869.8	18968.74	0	9332.783
1991	366408	156531.3	245559.7	17178.52	0	8563.844	163180	34008.68	124185.6
1992	1015794	522072.5	647794.5	3292735	1729997	2173746	673847.8	277902.2	461473.5
1993	1009269	615917.6	518411.6	1825109	836340.8	1303233	798081.3	515406.4	350141.3
	1058628	742524.9	421406.1	2551237	1696954	1222276	850900.9	673201.4	270840.8
	35.64403	25.00084	14.18876	19.73114	13.12416	9.453025	18.74231	14.82822	5.965656

	Gymam	128.6	km2	Hizyz	75.2	km2
	Qup	Qtot		Qup	Qtot	
1974	1608540	690830.2	1160762	517732.4	78367.75	457636.4
1975	3588793	1537435	2677183	1110448	117812.9	1005343
1976	1612662	1069544	830073.2	599497.2	134871	531346.9
1977	11770016	9995976	2847390	7718726	3138704	6140205
1978	300328.5	3862.938	263928	11784.96	0	5715.949
1979	475978	84894.11	419996.4	56465.24	0	43003.66
1980	698312.5	361593.9	443697.6	122097.1	7448.053	108481.9
1981	3711274	2481980	1775520	1475820	389590.5	1268529
1982	3835882	2514046	1860941	1759758	548689.8	1479781
1983	5447748	3448306	3030913	2394788	577616.6	2107614
1984	2450652	2013943	789548.6	1524132	524163.1	1276695
1985	651922.9	133117.1	561692.8	126647.5	0	108702.3
1986	3013640	2065465	1500328	1361949	361143.9	1194319
1987	418275.5	32820.93	364888	27029.43	0	13258.94
1988	930666.7	398400.6	648096.8	269476.4	37188.12	236002.7
1989	1119833	428792.8	895268.7	315782	2745.969	289420.6
1990	151686.6	3929.147	133040.8	14518.53	0	8955.039
1991	11753.11	0	6298.474	0	0	0
1992	3002384	1389121	2130971	927701.1	167806.9	809807.6
1993	1665296	667966.2	1263865	503723.1	45612.72	454373.1
	2323282	1466101	1180220	1041904	306588	876959.5
	18.06596	11.40048	9.17745	13.8551	4.076969	11.6617

Appendix E

(E-1 TO E-6)

Urban Recharge data

WELL INVENTORY DATA

A WELL IDENTIF. OWNER:
LOCATION:

COORDINATES : N
E ELEVATION: m+ msl

B WHEN CONSTRUCTED:
TOTAL DEPTH: m

C PUMP INTAKE at m PUMP RUNS DRY NO/YES
YIELD (estim/meas) l/sec AFTER hrs/min

D AVERAGE PUMPAGE DURATION
hrs/day days/week months/year
WATER USE: domestic/irrigation/water supply/other

E ORIGINAL DEPTH TO (static) WATER LEVEL: m
ACTUAL DEPTH (meas/estim) TO WATER LEVEL: m (stat/dyn)

F TEMPERATURE C°
EC

G

DATE:
REMARKS:

LOCATION SKETCH:

SUMMARY OF THE WELL INVENTORY MARCH-SEPTEMBER 1993
OVER SANA'A CITY

serial num	Well numb	Location N	E	Depth	Year	Yield l/s	Duration	SWL	EC	PUMP, USES, AND REMARKS	Total disch
1	1	152010	441231	300	1984		7300			dom	0
2	1	152010	441231	350	1972		2900			dom	0
3	2	152022	441244	60	1960		700	48.19	1000	dom,mosq	0
4	3	152034	441250	60	1970		200	49.1	1500	dom	0
5	3	152034	441251	300	1900		1460				0
6	4	152011	441243	65	1960	3.4	3000	47.4	1000	mosq,irr,dom	36720
7	5	152031	441237	280	1988		3000			W.supply80H,mosq.	0
8	6	152044	441222	60	1973		4380		870	pump 59, sale water	0
9	7	152047	441217	150	1984		4400		520	w.supply.,2mosq.	0
10	8	151526	441052	200	1979		730		500	w.supply,irrig	0
11	9	151952	441201	150	1900	8.1	3000		420	sales w.,irr,dom	87480
12	10	152056	441206	50	1978		200		1100	dom, irr	0
13	11	152030	441319	160	1988	2.5	730		745	pump at 80, irrig, dom	6570
14	12	152016	441138	300	1975	4 1	1825		540	irr	26937
15	13	152019	441142	60	1960		200	54.29	640	2hous.mo	0
16	14	152019	441142	50	1960		1100	54 93	650	dom.irr30k	0
17	15	152028	441148	200	1965		700			aut.pump to tank	0
18	16	152013	441049	300	1991		2200			dom. sale water	0
19	17	152009	441109	120	1978		700			it was selling water	0
20	18	1695000	412000	200	1984		3650				0
21	18	1695000	412000	200	1980		3650				0
22	19	152008	441029	150	1988		1100	114	700	pump 18k	0
23	20	152004	441109	250	1986		3000			irr,service cars	0
24	21	152026	441045	100	1989		2000			start work a week ago	0
25	22	152016	441127	75	1962		1100	57.03	580	irr 750km	0
26	23	152100	441048	160	1985		0			6-7hrs first	0
27	24	152116	441051	300	1979		4700		770	90 houses	0
28	25	152134	441049	180	1980	5.5	3000		510	sale water+mosq	59400
29	26	152147	441035	250	1975	3.5	6200		520	it was 150, then deepen to 350 a	78120
30	27	152131	441112	70	1962	4.1	2500		480	dom.sale water,irr.	36900
31	28	152127	441056	70	1960	3	3000		770	dom.,irr.,w.suply	32400
32	29	152112	441107	350	1977	5	3600			the yield was 15 l/s	64800
33	30	152112	441107	60	1963		1500		1300	dom.,irr.,mos.	0
34	31	152124	441125	70	1970		1500		800	pump 69 sale water, dom, irrig	0
35	32	152133	441130	60	1900		3300		620	pump 51, sale water to 55 house	0
36	33	152141	441131	80	1960		1800		550	houses,irr.	0
37	34	152113	441131	40	1900		0			out of use	0
38	34	152113	441131	120	1970		0			NAWSA,out of use	0
39	35	152056	441134	370 '	1989		3600			it was hand then deepened	0
40	36	152108	441135	60	1900		3000		2100	pump 54	0
41	37	152119	441139	60	1900		1800		1450		0
42	38	152109	441148	60	1900		700				0
43	39	152123	441159	200	1983		3600		2195	Russian embassy	0
44	39	152123	441159	200	1978		3600				0
45	39	152123	441159	200	1976		3600				0
46	40	152121	441158	45	1900	2	2200	40.36	1150	irrigation	15840
47	41	152121	441158	280	1990		0	42		no pump	0
48	42	152117	441150	60	1900		1800		1100		0
49	43	152117	441150	70	1900		1800		1050	pump 60, irrig, dom	0
50	44	152038	441143	60	1960		200		1100	it was for irr.,now dom.only	0
51	45	152045	441140	150	1978		4400		890	dom.,irr.,mosq.	0
52	46	152108	441144	60	1900	4	2200		1400	irr.,mos.	31680
53	47	152106	441152	70	1960		1800		1300	dom.,irrigation	0
54	48	152050	441159	200	1973		3600			Chinese Embassy	0
55	49	152142	441136	300	1970		4400			6 years ag	0
56	50	152138	441200	87	1982		2200		825	dug/drill sale water	0
57	51	152136	441207	20	1960		1500		900		0
58	52	152132	441159	40	1900		0			two dug wells ,out of use	0
59	53	152128	441212	200	1978		1800			borehole belong to NAWSA	0
60	54	1699500	417000	200	1977	8	3600				103680
61	55	1699000	416500	200	1963	7	3600				90720
62	56	1699000	416500	180	1965	9	4800				155520
63	57	1699000	416500	200	1980		7300				0
64	58	1697600	414360	60	1960		1100		1100	mosque	0
65	59	1697600	414210	60	1960		1800		1100	pump 45	0
66	60	1697500	414200	60	1960		1800		1250		0
67	61	152119	441211	200	1972		2200			irrigation	0
68	62	152113	441207	60	1960		1100		1500	dom.,irrigation	0
69	63	1697500	414200	60	1960		400		1500		0
70	64	1697400	414100	60	1960		700		1600		0
71	65	152144	441159	60	1900		2500		600		0
72	66	152154	441144	250	1962	6.8	2200		410		53856
73	67	152201	441147	65	1960		1100				0
74	68	152128	441220	200	1960		4400			pump 180, water suppl, 600 hous	0
75	69	152135	441200	60	1900		700		1700	mosque	0
76	70	152132	441228	70	1900		1400			irrigation	0
77	71	152119	441218	200	1987	7.6	1800		530	pump 160,casing up 120	49248
78	72	152105	441210	60	1900		1200				0
79	73	1697500	414500	60	1900		3300		1100	pump 48	0
80	74	152054	441200	150	1962		2200		1150	pump 60	0
81	75	152054	441200	60	1900		3300		1100		0
82	76	152054	441200	60	1900		2200		1200		0
83	77	152212	441230	95	1976		1500			sale water	0
84	78	152214	441247	65	1900		2800			sale water + block fac.	0
85	79	152207	441241	80	1900		3600		1780		0
86	80	152202	441238	275	1988		3600		850	pump 120 irrig.domand supply	0

87	81	152210	441307	130	1972		700		700	sale water	0
88	82	152202	441254	60	1900		1800			mosque	0
89	83	152143	441240	60	1900		0		1200	imgation	0
90	84	152144	441242	120	1972		1200			pump 84, out of use	0
91	85	152138	441248	60	1900		5500			mos	0
92	86	152138	441228	220	1989	8 6	2500		1200	casing 200, screen from 100	77400
93	87	152202	441311	200	1986		2500			img +water supply	0
94	88	152159	441301	120	1967	4 3	360		1000		5572.8
95	89	152159	441301	300	1993		0				0
96	90	152155	441302	60	1900		2500		1100		0
97	91	152155	441303	40	1900		5100				0
98	92	152204	441259	300	1975		700			dom,img,supply	0
99	93	152141	441303	200	1979		2200			pump 120, dom,ing.sup,mos	0
100	94	152141	441302	85	1900		1800		3400	irr+mosq	0
101	95	152147	441307	200	1980		4700			img 4 mos, it was dug then drilled	0
102	96	152139	441258	220	*1993*		*6500*			*pump(120)+ img+mosq*	0
103	97	152121	441310	40	1900		700				0
104	98	152120	441310	180	1980		4700			img, 18 mosq	0
105	99	152118	441322	240	1988		6500		1010		0
106	100	152118	441311	260	1979		3600		1010		0
107	101	152151	441331	200	1970		700			img	0
108	102	152113	441303	200	1973		0				0
109	103	152059	441348	250	1987	7.2	3600			img+bath	93312
110	104	152059	441349	550	1991		7300				0
111	105	1697600	417600	70	1900		700				0
112	106	152105	441316	175	1984		3600				0
113	106	263205	441316	114	1963		0				0
114	106	1697000	416500	114	1970		0				0
115	106	1697000	416500	300	1993		0			need cables	0
116	107	1697200	416200	80	1900		700			out of use	0
117	108	152112	441342	180	1962		5100			dom,supply	0
118	109	1699000	412000	200	1970		7200				0
119	110	1699500	412500	250	1973		7200				0
120	111	152212	441153	80	1900		1500			pump(70)dom,img,mosq	0
121	112	152204	441150	60	1900		1800		800	dom,img,mos	0
122	113	152213	441209	60	1900		0				0
123	114	152227	441225	200	1980		4400		1230	img,mosq	0
124	115	152221	441230	65	1900		1800		1200	pump(45),img	0
125	116	152220	441239	60	1900		1500		1100	pump 50	0
126	117	1698200	415400	60	1900		1200				0
127	118	152249	441222	60	1900		0				0
128	119	152224	441248	60	1900		1500		1400		0
129	120	152230	441252	200	1979		1800		1100	mos,img	0
130	120	152230	441252	60	1900		1100		1100	img	0
131	121	152232	441248	50	1900	4.2	2200		1500	pump39, img	33264
132	122	152237	441333	200	1980		4200			sale water ,img	0
133	123	152307	441312	300	1983		5500			pump150,doms,sale water	0
134	124	152257	441311	180	1987		5500			dom,sale water	0
135	125	152245	441223	350	1973		2500			dom, img,sup,mosq	0
136	126	152259	441230	60	1900		1800			irrig	0
137	127	152303	441229	70	1900	3 6	700		2400	img	9072
138	128	152303	441229	7	1985	2.6	1100	3	2700	img	10296
139	129	1702300	413800	200	1980		2900			supply 200 house, img	0
140	130	2801850	414700	6	1982		400	3 2	2600	irrig,	0
141	131	152125	441250	200	1986		1460				0
142	132	152132	441238	60	1900		0				0
143	133	152138	441238	270	1986	8	6500		1500	img, mosq	187200
144	134	152120	441240	50	1900		700	40 6			0
145	135	152109	441242	200	1975		4700		1300	pump, 180 mos	0
146	136	152109	441227	84	1900		200		1010	pump78, mos	0
147	137	152112	441231	150	1983		7300		950		0
148	138	152112	441231	60	1900		0				0
149	139	152126	441256	40	1900		0				0
150	140	152126	441256	250	1992		700		1010	pump 240, img,mosq	0
151	141	152121	441215	200	1970		700		1090		0
152	142	1697100	415200	250	1985		2200		2190		0
153	142	1697100	415200	50	1900		1100				0
154	143	1798000	415000	60	1900		1800		720		0
155	144	1697800	415200	60	*1900*		*2200*	*45.52*			0
156	145	1697500	415000	70	1900		2700				0
157	146	1698800	415150	60	1900		700				0
158	147	1696000	416900	200	1993		700				0
159	148	1695300	416200	350	1975		3600				0
160	150	1700700	415800	70	1900		1100			dom,irrig	0
161	151	1701400	415000	200	1980		2900			sale water, mosq, img	0
						122.1	372645				1345987.8
						5.3086957					58521.217

19 wells taken from reports

162	almafa	1701900	416800	average		7121732	m3/year
163	central jail	1702900	416300	7 hours work			
164	almotoukel	1702700	415700			49115.393	m3/year/well
165	hidagat althowra	1701200	415200				
166	alhasaba	1700000	413200		191.4	9400686.3	
167	alhasaba	1699500	414000		2029600		Total discharge is
168	alhasaba	1698500	413200				11430286
169	bustan alhasaba	1699800	413700				
170	alkasara	1698700	411600				
171	alkasara	1698100	411600				
172	garden 60streat	1695900	412300				
173	the scout	1704000	414000				
174	alistad alndı	1704300	413700				
175	german embassy	1694500	413400				
176	british council	1694900	415500				
177	jordan embassy	1694800	413500				
178	*streat 60*	1694000	413800				

ESTIMATES OF URB	ITALOCONSULT, 1972		MOS. 1984		ALDERWISH, 1993	HWC 1990
ABSTRACTION	m3/year	annual		annual		
NWSA	1022000	rate	9125000	rate	17523900	12500000
domestic	1402000	339416.7	5475000	245322.2	7682900	6700000
Industrial	661000	97000	1825000	202555.6	3648000	4700000
irrigation	1273200	45983.33	1825000	27122.22	2069100	0
TOTAL	3336200		9125000		13400000	11400000

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
water supplied	2498000	2866533	3235067	3603600	3972133	4340667	4709200	5742034	8368907	8727500	9888084
INTERPOLATION											
domestic	1402000	1741417	2080833	2420250	2759667	3099084	3438500	3777917	4117334	4456750	4796167
Industrial	661000	758000	855000	952000	1049000	1146000	1243000	1340000	1437000	1534000	1631000
Irrigation	1273200	1319183	1365167	1411150	1457133	1503117	1549100	1595083	1641067	1687050	1733033
total private	3336200	3818600	4301000	4783400	5265800	5748200	6230600	6713000	7195400	7677800	8160200
NAWSA	1022000	1022000	1022000	1022000	1022000	1022000	1022000	1971000	5197200	5183000	6314500
domestic+indust	3085000	3521417	3957833	4394250	4830667	5267084	5703500	7088917	10751534	11173750	12741667
TOTAL	4358200	4840600	5323000	5805400	6287800	6770200	7252600	8684000	12392600	12860800	14474700
WATER BALANCE COMPONENTS											
NWSA 30%	153300	153300	153300	153300	153300	153300	153300	295650	779580	777450	947175
USING 50% OF LOSSES											
PRIVATE 20%	140200	174141.7	208083.3	242025	275966.7	309908.4	343850	377791.7	411733.4	445675	479616.7
NET SUPPLIED WAT FOR DOMESTIC USE	1837000	2108533	2380067	2651600	2923133	3194667	3466200	4402034	6931907	7193500	8257084
THE EXPORTED PA TANKERS+SEWER	200000	200000	200000	200000	200000	200000	200000	200000	200000	200000	200000
SUPPLIED-SEWEAG	1637000	1908533	2180067	2451600	2723133	2994667	3266200	4202034	6731907	6993500	8057084
80% OF CESSPITS	1309600	1526827	1744053	1961280	2178507	2395733	2612960	3361627	5385526	5594800	6445667
INDUSTRIAL 25%	165250	189500	213750	238000	262250	286500	310750	335000	359250	383500	407750
Irrigation R 34%	432888	448522.3	464156.7	479791	495425.3	511059.7	526694	542328.3	557962.7	573597	589231.3
Alsyla	0	0	1078811	2358784	381015	4183602	240247	405	753373	640245	3150526

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
water supplied	10767617	13059204	12983811	12989352	13847024	15737876	16350722	17424256	18976680	22505541	22061051
INTERPOLATION											
domestic	5135584	5475000	5720323	5965645	6210967	6456289	6701611	6946934	7192256	7437578	7682900
Industrial	1728000	1825000	2027556	2230111	2432667	2635222	2837778	3040334	3242889	3445445	3648000
Irrigation	1779017	1825000	1852122	1879244	1906367	1933489	1960611	1987733	2014856	2041978	2069100
total private	8642600	9125000	9600000	10075000	10550000	11025000	11500000	11975000	12450001	12925001	13400001
NAWSA	7044500	9791720	9114282	8552464	9207976	11339460	11645221	12609108	14257123	18728620	17523900
domestic+indust	13908084	17091720	16862160	16748220	17851610	20430972	21184610	22596375	24692268	29611643	28854801
TOTAL	15687100	18916720	18714282	18627464	19757976	22364460	23145221	24584108	26707124	31653621	30923901
WATER BALANCE COMPONENTS											
NWSA 30%	1056675	1468758	1367142	1282870	1381196	1700919	1746783	1891366	2138568	2809293	2628585
USING 50% OF LOSSES											
PRIVATE 20%	513558.4	547500	572032.3	596564.5	621096.7	645628.9	670161.1	694693.4	719225.6	743757.8	768290
NET SUPPLIED WAT FOR DOMESTIC USE	9039617	11234204	10956255	10759241	11414357	13102653	13512944	14383922	15733791	19060096	18413050
THE EXPORTED PA TANKERS+SEWER	200000	200000	200000	2737500	2737500	2737500	2737500	2737500	2737500	2737500	2737500
SUPPLIED-SEWEAG	8839617	11034204	10756255	8021741	8676857	10365153	10775444	11646422	12996291	16322596	15675550
80% OF CESSPITS	7071694	8827363	8605004	6417393	6941485	8292123	8620355	9317138	10397033	13058077	12540440
INDUSTRIAL 25%	432000	456250	506888.9	557527.8	608166.7	658805.6	709444.5	760083.4	810722.3	861361.2	912000.1
Irrigation R 34%	604865.7	620500	629721.5	638943.1	648164.7	657386.2	666607.8	675829.3	685050.9	694272.4	703494
Alsyla	4196546	726755	806360	2076718	98064	736847	104969	35483	0	342016	983048.2

WATER BALANCE COMPONENTS ,RECHARGE

TOTAL ABSTRACTED PUB.&PRI DOM+IND	with irrigation		MAINS NWSA	MAINS PRIVATE	CESS-PITS	industry	Irrigation	wadi	TOTAL RECHARGE dom+indus	+irrigat	+Wadi	PERCENTAGE rech/abst	water supplied	PERCENT RECH/SU
3085000	4358200	1972	153300	140200	1309600	165250	432888	0	1768350	2201238	2201238	57.32091	2498000	70.79063
3521417	4840600	1973	153300	174141.7	1526827	189500	448522.3	0	2043768	2492291	2492291	58.03824	2866533	71.29756
3957833	5323000	1974	153300	208083.3	1744053	213750	464156.7	1078811	2319187	2783343	3862154	58 59738	3235067	71.68899
4394250	5805400	1975	153300	242025	1961280	238000	479791	2358784	2594605	3074396	5433180	59.04546	3603600	72.00036
4830667	6287800	1976	153300	275966.7	2178507	262250	495425.3	381015	2870023	3365449	3746464	59.41257	3972133	72.25395
5267084	6770200	1977	153300	309908.4	2395733	286500	511059.7	4183602	3145442	3656501	7840103	59.71885	4340667	72.46448
5703500	7252600	1978	153300	343850	2612960	310750	526694	240247	3420860	3947554	4187801	59.97826	4709200	72.64206
7088917	8684000	1979	295650	377791.7	3361627	335000	542328.3	405	4370069	4912397	4912802	61.64649	5742034	76.10664
10751534	12392600	1980	779580	411733.4	5385526	359250	557962.7	753373	6936089	7494052	8247425	64.51255	8368907	82.87927
11173750	12860800	1981	777450	445675	5594800	383500	573597	640245	7201425	7775022	8415267	64 44949	8727500	82.51418
12741667	14474700	1982	947175	479616.7	6445667	407750	589231.3	3150526	8280209	8869440	12019966	64.98528	9888084	83.73927
13908084	15687100	1983	1056675	513558.4	7071694	432000	604865.7	4196546	9073927	9678793	13875339	65.24211	10767617	84.27052
17091720	18916720	1984	1468758	547500	8827363	456250	620500	726755	11299871	11920371	12647126	66.11313	13059204	86.52802
16862160	18714282	1985	1367142	572032.3	8605004	506888.9	629721.5	806360	11051068	11680789	12487149	65.53768	12983811	85.11421
16748220	18627464	1986	1282870	596564.5	6417393	557527.8	638943.1	2076718	8854354	9493297	11570015	52.86744	12989352	68.16625
17851610	19757976	1987	1381196	621096.7	6941485	608166.7	648164.7	98064	9551945	10200110	10298174	53.50747	13847024	68.98194
20430972	22364460	1988	1700919	645628.9	8292123	658805 6	657386.2	736847	11297476	11954862	12691709	55.29583	15737876	71.78527
21184610	23145221	1989	1746783	670161 1	8620355	709444.5	666607.8	104969	11746744	12413352	12518321	55.44942	16350722	71.84236
22596375	24584108	1990	1891366	694693 4	9317138	760083.4	675829.3	35483	12663281	13339110	13374593	56.0412	17424256	72.67616
24692268	26707124	1991	2138568	719225.6	10397033	810722.3	685050.9	0	14065549	14750600	14750600	56.96337	18976680	74.12018
29611643	31653621	1992	2809293	743757.8	13058077	861361.2	694272.4	342016	17472489	18166762	18508778	59.00547	22505541	77.63639
28854801	30923901	1993	2628585	768290	12540440	912000.1	703494	983048.2	16849315	17552809	18535857	58.39346	22061051	76.37585
			1061141	477340.9	6118395	473852.3	583931.4	1144691	8753196	9351450	10496141	59.64191		75.72157

Analysis abstraction- Recharge urban area aquifer

Urban	Total private abstract	urban recharge	Differece	AQUIFER WATER LEVEL Total percent	cumulative
1972	3336200	2201238	-1134962	65.9804	-1134962
1973	3818600	2492291	-1326309	65.26713	-2461271
1974	4301000	3862154	-438846	89.79666	-2900117
1975	4783400	5433180	649780	113.5841	-2250337
1976	5265800	3746464	-1519336	71.14709	-3769673
1977	5748200	7840103	2091903	136.3923	-1677770
1978	6230600	4187801	-2042799	67.21345	-3720569
1979	6713000	4912802	-1800198	73.1834	-5520768
1980	7195400	8247425	1052024	114.6208	-4468743
1981	7677800	8415267	737466.9	109.6052	-3731276
1982	8160200	12019966	3859766	147.2999	128489.3
1983	8642600	13875339	5232738	160.5459	5361228
1984	9125000	12647126	3522126	138.5986	8883354
1985	9600000	12487149	2887149	130.0745	11770503
1986	10075000	11570015	1495015	114.8389	13265518
1987	10550000	10298174	-251827	97.61302	13013691
1988	11025000	12691709	1666709	115.1175	14680400
1989	11500000	12518321	1018320	108.855	15698720
1990	11975000	13374593	1399593	111.6876	17098313
1991	12450001	14750600	2300599	118.4787	19398912
1992	12925001	18508778	5583777	143.2014	24982689
1993	13400001	18535857	5135857	138.3273	30118546
	priv.dome +industry +irrigation	10496141			

Appendix F

(F1 TO F4)

Hydrochemistry data

Serial no	Eastern part well no	Name	depth m	pump depth	casing m	aqurfer(S)	Eh volts	PH	DO mg/l	Temperau C	EC	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	SiO2 mg/l	Iron	Al	error ion balance %
Rujam																								
1	1	alQadam	spring	-	-	TV	-0 035	7 57	8 1	20 9	440	469	44 00	7 86	70 20	2 20	248 88	32 45	39 95	1 45	22 14	0	11 9	0 869933
2	2	alqadam	380 0	222	240	CSS	-0 200	10 70	4 7	26 6	915	754	91 00	24 37	92 80	4 90	317 20	97 50	116 80	0 00	9 49	2550	1 3	1 551903
3	3	almagrbi	400 0	201	no	CSS	-0 048	7 80	6 2	26 1	490	401	63 50	16 03	27 10	2 40	176 90	29 18	77 23	0 00	8 63	1900	2	3 594644
4	4	alagil	220 0	120	no	CSS	-0 044	7 75	6 6	23 9	725	603	98 20	19 31	46 10	6 70	224 48	77 80	95 70	22 25	12 80	938 1	3 2	2 608473
5	5	Hizam	340 0	150	no	CSS	-0 067	8 15	0 7	24 4	500	474	78 20	13 53	27 70	3 30	242 78	25 95	74 05	0 00	8 28	1740	2	0 414027
6	75	alJardi	250 0	150	no	CSS	-0 023	7 40	1 2	25 1	620	559	100 00	16 91	33 20	2 30	247 66	37 43	79 28	28 48	13 65	139 7	15	4 364896
7	74	almalika	200 0	-	-	CSS					450	399	61 80	13 48	29 70	2 80	197 64	35 00	46 20	2 08	10 29	41 7	0	3 103873
8	J	NWSA	101 0	-	136	CSS	-0 028	7 48	0 8	24 8	530	436	61 21	15 41	40 93	4 60	209 96	41 41	53 03	0 00	9 78	115 9	2 6	4 249051
Alser																								
9	6	Alsayd	40	30	no	ALL	-0 045	7 75	9 6	21 2	1450	1119	230 90	40 40	76 30	4 90	173 24	382 10	168 68	24 42	18 32	967 10	12 7	2 140331
10	7	malik	260	165	21	CSS	-0 126	10 39	5 7	23 4	730	665	103 90	31 29	50 00	4 40	186 05	90 78	189 63	2 13	7 13	7510 00	5 4	2 313164
11	8	alSalahi	300	120	12	CSS	-0 133	9 21	3 0	23 9	1200	1059	172 20	49 64	77 50	6 90	389 18	169 86	184 93	0 00	9 12	2010 00	0	3 655699
12	9	alShana	110	84	9	CSS	-0 044	7 76	7 3	22 1	840	637	111 20	18 80	49 90	2 80	213 50	91 08	105 43	28 23	15 62	>1000	8 2	3 428939
13	10	alSiraji	150	91	no	CSS	-0 054	7 94	6 9	22 5	580	471	81 50	16 73	29 20	3 30	207 64	39 83	70 35	11 40	10 94	>1000	1 1	4 800397
14	11	alGiza	200	159	no	CSS	-0 010	7 20	6 4	23 0	810	666	107 10	24 94	58 40	4 60	231 20	82 70	148 50	0 00	8 32	>1000	8 6	4 36232
15	12	alSubaha	300	165	-	CSS	0 060	5 94	3 2	23 1	980	767	128 90	27 96	68 00	7 20	239 12	137 23	126 28	22 23	10.27	841 40	6 6	4 842391
16	70	alGaradha	250	150	24	CSS	0 019	7 20	6 5	25 7	1100	826	121 60	30 00	87 80	3 90	241 56	126 53	100 65	103 90	9 8	257 70	9 7	4 864458
17	71	alInab-D	30	45	-	ALL	0 011	6 80	7 5	26 1	960	729	117 20	23 14	71 70	2 50	222 04	115 25	117 95	41 43	18 19	364 10	2 6	4 395975
18	72	alInab-B	250	120	60	CSS	0 014	6 75	8 1	24 6	860	646	99 97	23 96	65 53	3 60	233 02	108 58	96 13	5 45	9 48	130 50	2 3	4 93388
19	73	alslahi-D	30	20	-	ALL	0 007	7 41	7 4	19 9	780	613	109 85	20 78	45 92	1 80	186 90	102 18	91 80	35 00	18 51	136 40	7 4	4 607041
20	136	Canada dr	180	160	-	ALL/AMR		6 5	0	29 6	610	628	49.2	12 78	118 8	5 1	187	28 1	218 0	9 5		(60)		1 471528
21	140	alsir alsya	40	30	-	ALL		7 01	5 3	21 3	1200	1016	212 1	35 08	42	3 9	208	134 0	351 0	30 4		(10)		1 348879
22	141	Alsayd dee	220	105	18 0	ALL/CSS		6 3	0	23 6	1100	1000	157 3	48 54	70	6 9	240	104 0	373 0	0 0		(190)		1 454045
23	142	alShana	200	-	-	CSS		6 6	4 1	24 7	700	511	89 3	15 5	36 5	2 4	162	45 4	148 0	11 6		(0)		1 20894
alRawna																								
24	21	hinish	300	180 0	12	TV/CSS	-0 109	8 02	3 9	25 4	540	476	75 41	15 17	33 90	2 90	254 98	28 78	53 55	0 00	11 51	450 7	0	3 58607
25	22	alHadi	450	255 0	440	CSS	-0 144	8 85	0 2	31 1	615	499	77 30	17 60	42 70	5 00	217 64	57 20	70 33	0 00	10 79	>1000	1 2	4 63494
26	23	alGadi	300	240 0	without	CSS/TV	-0 126	9 07	0 5	32 9	505	432	58 60	12 53	46 80	3 40	207 76	36 60	53 25	0 00	12 93	617	0	4 573749
27	24	Alisha	280	195 0	160	CSS	-0 023	7 91	0 4	25 5	615	572	94 39	18 76	37 00	3 00	305 36	32 25	68 63	0 00	12 82	1460	2	3 903291
28	25	Rawna-D	30	-	-	ALL	0 009	6 85	7 0	19 3	930	816	133 1	24 79	77 3	3 8	269 62	130 83	99 13	54 55	23 09	804 6	0	4 690019
29	26	alHissin	550	450	480	TV/CSS	-0 077	8 81	0 1	36 3	770	520	76 2	18 13	52 6	2 3	230 82	46 69	83 77	0	11 04	2540	2 1	4 415161
30	E	NWSA	231		117	CSS	-0 029	7 49	3 7	24 6	590	512	83 00	15 09	39 20	2 70	235 94	39 80	63 08	17 80	15 24	79 4	2 9	4 127647
31	G	NWSA	227		142	CSS	-0 020	7 34	2 6	24 0	590	529	86.50	16 75	38 10	1 80	262 78	34 78	54 08	18 45	16 09	136 8	1 1	4 86507
32	134	almitla'a,D	300	135		CSS		6 45	2 4	24 5	700	559	90 1	17 14	45 4	2 4	207	46 3	141 0	9 3		(20)		1 006221
33	135	Surf,Foug	250	135		CSS		6 45	5 7	25 6	610	491	76 8	22 25	29	4 7	201	48 3	109 0	0 0		(0)		0 849494
62	63	darbouh	200	170	192	CSS	-0 157	7 82	2 1	23 9	650	581	93 50	17 79	48 10	2 70	239 36	64 38	69 84	21 50	23 95	721 7	18 5	4 743001
63	64	muhdism	300	210		TV/CSS	-0 003	6 82	1 6	25 4	560	455	55 40	9 60	65 80	2 50	175 07	59 12	69 17	0 00	17 91	704 3	3 3	4 040798

Western Part	well no	Name	depth m	pump depth	casing m		Eh volt	PH	DO mg/l	Temperau C	EC	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	SiO2 mg/l	Iron		error ion balance %
34	13	alman	200 0	120	12	CSS	-0 061	7 30	4 0	24 2	760	736	99 80	39 35	48 00	4 80	335 50	41 58	151 65	0 00	15 10	359 8	2 9	2 960525
35	14	altar	245 0	150	3	CSS	0 020	6 68	7 9	24 6	640	576	81 20	22 74	45 60	3 20	307 44	37 15	46 30	12 90	19 00	294	5 4	4 785177
36	15	masoudi	160 0	141	12	TV/CSS	-0 101	8 71	6 9	17 7	475	507	57 90	27 10	36 40	4 80	307 44	20 59	39 59	0 00	12 93	172	2 3	2 874288
37	16	Ozan	200 0	75		CSS	-0 089	7 77	5 3	21 9	500	500	73 60	19 64	32 70	3 80	296 50	20 33	31 60	5 30	16 50	220 5	20 2	4 866566
38	17	shawish	330 0	185	90	CSS	-0 110	8 14	3 4	22 9	515	554	59 20	29 71	45 30	5 30	336 72	23 85	39 55	0 00	14 79	375.2	3 9	3 374349
39	18	na am	250 0	150	200	QV	-0 057	7 63	2 8	22 7	360	340	11 50	4 63	69 70	2 70	183 00	14 53	20 70	0 00	32 98	417 8	6 9	2 730883
40	19	m base	200 0			QV/TV	-0 094	8 61	5 6	26 5	390	368	39 00	19 06	38 50	3 90	219 84	12 25	27 95	0 00	12 54	489 4	3 9	3 687607
41	20	alsada	300 0	180	150	QV/TV	0 027	6 95	2 6	26 2	470	402	35 70	10 65	61 60	4 60	211 06	20 88	43 60	0 00	13 82	268 9	3 1	4 793293
42	69	nshan	300 0			TV	-0 055	7 09	2 5	27 7	390	340	38 10	10 65	37 70	3 20	193 58	11 93	27 00	0 00	17 51	724 4	473 2	4 992774
43	130	Twzan als	135	132		ALL/TV		7 2	4 8	24 3	385	327	43 1	19 67	24 8	2 6	167	29 4	34 0	11 2		(0)		0 53752
44	131	Twzan ulia	330	330	180 0	TV/?		6 4	0 2	28 6	630	628	86	14	72 5	4 3	268	66 5	93 0	24 0		(0)		0.666735
45	133	Tang Amra	175	126		ALL/TV		6 97	4	22 6	440	358	39 7	14 55	37 5	4 1	179	34 6	37 0	11 4		(0)		0 519348
46	137	behind TV	200			CSS		7 4	0 4	24 4	480	420	59 2	20 18	23 9	3 2	227	28 4	47 0	11 5		(200)		0 441862
47	143	alHajib dh	150	90		CSS		6 66	3 4	21 6	590	538	84 6	22 32	30 2	2 1	274	41 6	72 0	11 5		(0)		0 514606

F 1

Central part	well no.	name	depth m	Pump depth	Casing m		Eh volt	PH	Do mg/l	Temper C	EC	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	SiO2 mg/l	Iron		error ion balance %
South																								
48	30	Bayt bous	250 0	120	30	TV	0 002	6 96	1 0	23 6	330	301	21 80	1 59	56 80	1 20	142 74	19 18	25 48	0 00	32 70	>1000	13	4 334276
49	31	Mahdi,bou	360 0	168	12	TV	-0 002	7 22	3 6	23 9	475	358	5 00	0 23	106 00	0 90	104 43	33 73	85 30	0 00	22 15	757 5	9.9	4 960343
50	32	wahas	230 0	106	30	TV	0 001	7 21	1 8	25 8	310	256	14 40	0 15	58 60	0 90	92 00	22 63	48 70	0 00	18 64	966 8	3 3	2 209718
51	33	najad,artil	230 0	132	48	TV	0 008	7 06	5 7	23 4	425	418	60 60	8 24	40 40	1 80	201 05	26 13	24 65	27 78	26 90	580 1	0	4 874824
52	34	malik,asir	300 0	189	30	TV	0 007	7 07	5 3	28 9	370	361	1 50	0 10	97 20	0 80	167 95	23 48	27 48	0 00	42 59	222 1	20 2	4 141607
53	45	golaisi	180.0	150	100	TV	-0.132	8 96	4 9	23 2	525	424	10 00	1 26	109 20	1 20	158 60	51 68	31 05	29 18	32 31	421.7	12 1	1 980479
54	46	abuahmed	250 0			TV	-0 076	7 99	4 4	23 6	510	446	32 00	5 51	87 50	1 80	183 00	45 10	34 60	24 05	32 10	394 2	3.1	4 631727
55	47	ossaimi	120 0			ALL/TV	-0 087	8 22	6 3	20 7	480	453	71 20	11 62	41 40	2 90	178 12	50 40	51 00	26 08	20 06	336 3	3 3	4 591401
56	48	ossaimi	250			TV	-0 044	7 48	3 5	24 1	400	350	33 30	4 14	61 10	1 40	134 44	38 90	37 48	13 65	26 07	492 8	5 2	4 386441
The city																								
57	49	hamami	200	105	180	TV	-0 103	8 46	5 5	23 2	530	436	58 00	7 34	66 50	1 30	122 00	97 50	36 98	18 38	27 50	253 2	3 3	4 965129
58	50	wishah	220	72	72	ALL	-0 044	7 47	5 8	22 7	800	731	132 40	21 67	59 80	4 00	186 66	143 78	99 73	59.23	23 60	336 9	8 6	4 455843
59	51	wishah	70	35		ALL/TV	-0.018	8 71	8 0	19 9	1750	1509	312 00	49 33	78 20	4 90	337 94	309 50	248 50	142.03	26 77	660	18.2	3 164781
60	52	atia	50			ALL	-0.047	9 22	8 7	19 2	2350	1979	366 50	61 46	149 70	6 10	345 26	429 90	525.40	65 83	28 57	328 1	38 4	0 379468
61	65	highway	200			TV	-0.044	7 54	3 9	24 0	1150	921	183 90	32 30	55 40	1 90	222 04	201.83	98.83	96 84	27.99	127	0 1	4 92024
North																								
64	53	thawara	200	192	170	CSS	-0 157	9 50	0 2	23 9	630	545	89 50	17 31	45 50	3 30	225 82	59 10	89 98	0 00	14 57	>1000	31 6	4 687894
65	54	m.coll	180			ALL/CSS?	-0.097	9.98	3 1	27 4	440	396	47 10	11 72	41 80	5 10	219 00	24 30	35 98	0 00	11 09	189 4	25.5	2.327778
66	55	shajara	200.0	120	100	ALL/CSS?	-0 091	8 54	2 3	24 1	600	574	93 50	17 19	48 90	3 30	226 92	60 00	106 20	3 90	14.42	180	2.6	3.79262
67	56	rassam	200 0	165	180	ALL	-0.026	7 45	7.3	24 3	515	389	18 50	4 62	91 50	3 00	149 08	52 35	46 40	3.60	19 94	332	5	4.036906
68	57	zubairi	50 0			ALL	-0 029	7 50	7 8	21 4	1900	1485	285 20	53 59	111 80	7 70	83 90	633.80	194 48	93 44	20 99	932.7	1 8	-2.28644
69	58	zubairi	300 0	165	200	ALL/CSS?	-0 041	7 68	6 3	26 2	540	425	25 80	7 03	100 20	3 70	118 58	83 38	68 17	1 57	16 71	461.7	3.7	4 80088
70	59	jail	260.0	150	200	ALL/CSS	0.009	6 85	3 7	22 5	660	573	90 30	17 64	47 10	3 00	251 56	53.23	69 50	17 98	22 23	586.1	3 3	4.671211
71	60	halali	420.0	165	100	ALL	-0.041	7.69	3 0	28 5	750	587	16 10	2 57	168.50	2.00	179 46	69 84	125.58	4 93	17 76	256 3	11.4	4.938019
72	61	algassim	180.0			ALL	-0.017	7 31	7 7	24 3	850	678	92.89	18 17	83.59	3 50	194 59	127 08	70 55	67 05	20.30	>1000	2 5	2.770961
73	62	marib	185	174		ALL	-0 008	7.14	6 5	26 8	430	322	23.1	3 89	69.5	2 7	96 88	54 75	37.35	15 68	17.7	>1000	12.1	4.608239
74	66	hizmi	200	138	162	ALL	0 001	6 97	3 4	26 8	750	548	15.7	3 29	149.7	2.9	159 82	42.73	154 78	4 48	14.27	147.8	11 8	3.52746
75	67	almaamar	350	147	138	ALL/?	0.002	6 95	1 7	29 4	1300	1038	32 30	8 10	271 40	3.10	364 17	44.25	292 45	8 94	13.40	135.2	8.7	2.583755
76	68	attif	200	120	140	ALL/?	-0 004	7.05	1 4	27 8	480	399	37.90	10.81	59 60	5.60	186.90	33.83	41.20	7.73	15.84	122.8	3	4.911311
77	125	alkhand	spring			KOHLAN/AMR		5.84		31 7	1200	1017	159 4	38.72	83 7	8.7	227	57.0	431.0	11.3				1.762193
78	144	plain	borehole			ALL/?		7	3 7	23 3	450	370	37.6	20.7	34 9	4 1	183	47.1	29.0	14 0				0.427609
79	145	hankel	150	72		ALL/?		7.3	1.7	33 4	580	417	29 7	14 55	69 4	3 7	197	68.3	15.0	19 6				0.076657
80	139	alirra	160	93		ALL/?		6.7	5 9	22.3	460	429	60	13 35	40.4	3.3	207	51.9	39.0	13.8				0.376296

Samples from second field work without major anions analysis

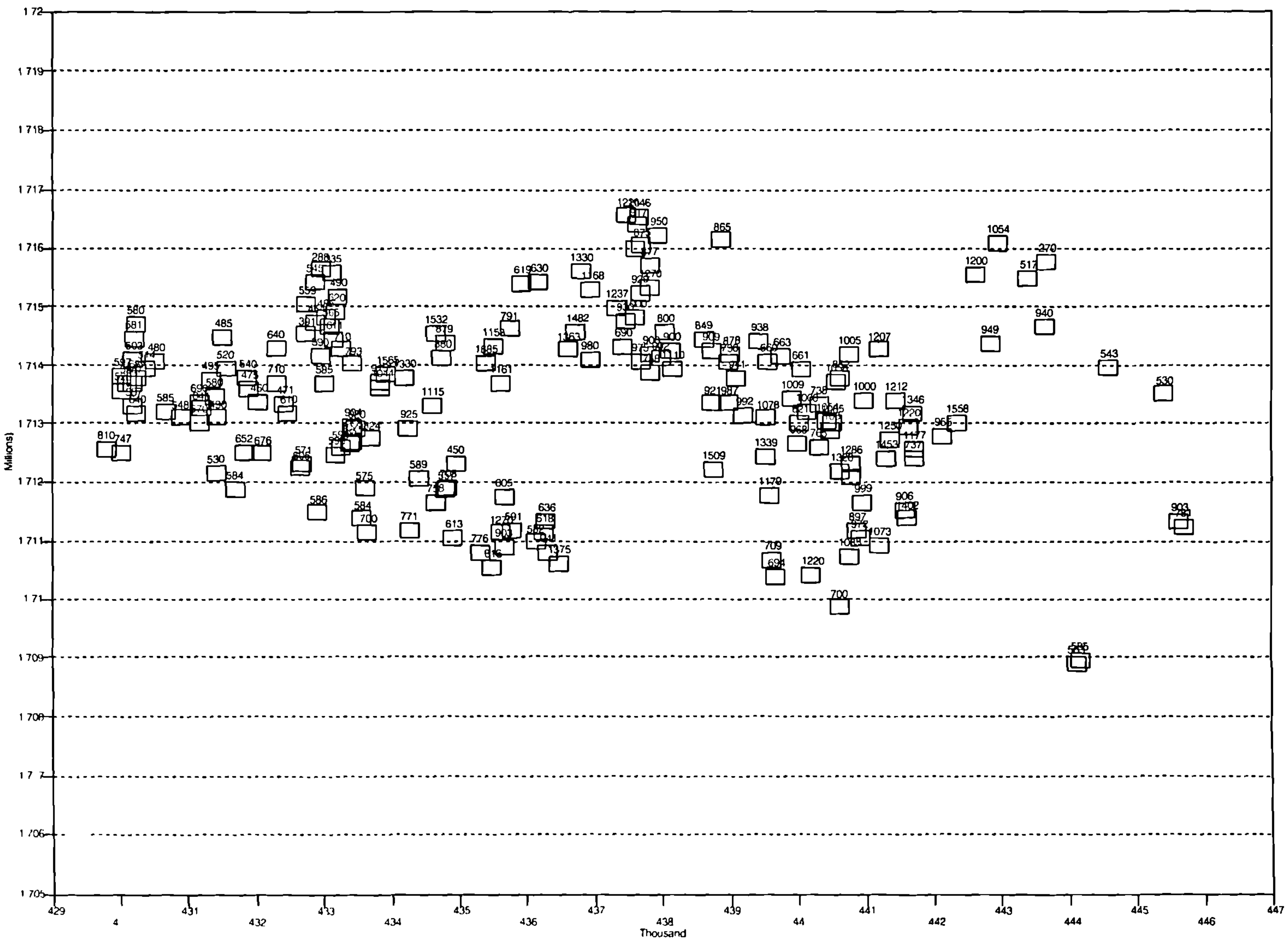
serial numb	well no	Name	depth	pump	casing	AQUIFER	Eh	PH		DO	Temperatur	EC	TDS	Ca	Mg	Na	K	HCO	CL	SO4	NO3
81	101	Atia,dug	D 70			ALL		7 28			19 9	820		127 9	19 54	41 9	2 9	153			
82	102	alRahbi	D 55			ALL		7 17				1200		171 2	26 93	59 9	3 3	128			
83	103	balas	D 80	swl 59 8		ALL		7 21				460		57 4	9 3	39 6	2	124			
84	104	alJamhori	180	casing up 1	100-40	ALL/TV		6 78				1000		153 2	24 48	42 2	3 7	210			
85	105	daralhamd	D			ALL		7 22				765		117 1	17 77	34 3	2 7	145			
86	106	baldia	D			ALL		6 83				920		141 7	21 24	33	3 2	156			
87	107	Ansar mosq	D			ALL		7.22				510		69 2	12 62	33 3	2.2	140			
88	108	Russ Emb	80			ALL/TV		6 83			21 2	1400		236 4	35 67	43 3	3 9	158			
89	109	alTwgih mil	190	162	120	TV		6 9			22 3	555		60	9.29	51 4	2 3	108			
90	110	alfadial has	D	swl 39 9		ALL		6 28			21	1550		258 8	41 84	51 6	4 1	300			
91	111	khiran	D			ALL		7 02			20 7	770		113 4	17 74	41	3 1	204			
92	112	gubat almh	D			ALL		7 08			20 3	1500		249 9	39 11	70 9	3 7	217			
93	113	alHurgan	D			ALL		7 06			20 4	1400		234 8	35 67	76 7	4	230			
94	114	alMshd,Mu	D			ALL		7 22			20 6	2600		478 9	77 18	81 5	4 5	165			
95	115	alBakaili m	150	96		ALL/TV		7 08			23	1300		176 1	27 5	67 5	2 8	154			
96	116	alGasham	D/Dr			ALL/TV		7 37			21 9	1100		151 3	23 19	77 2	3 7	87			
97	117	alTawgi,has	300	150	80	ALL/TV		7 57			24 8	430		35 4	8 09	43 5	2 5	131			
98	118	alAhmar	250	225	up to S S	ALL/TV		6 75			25 2	500		55 6	13 65	34 9	2 5	169			
99	119	Rashid,has	D 60			ALL		7 63			20 1	2700		296 5	62 73	229 9	2 6	145			
100	120	alZiba	D			ALL/TV		7 12			22 3	1200		202 6	35 84	56 2	4.2	373			
101	121	althwra,hidi	340	220		ALL/TV		6 77		4	25 1	570		64 4	15 8	38 4	3 1	176			
102	122	Alomain	220			ALL/TV		6 7		6	25 5	770		91 8	19 12	50 6	2 9	199			
103	123	seven/up	300	142	156-96	ALL/TV		7 18		1	27 6	540		31 7	11 76	63 3	5 4	126			
104	126	wadi njan	220	189	220-80	CSS/AM		6 43	'2 9		29 9	2350		315	52 91	195 2	12 3	193			
105	127	alzdfan	120	93	90	CSS		7	'4 6		28 9	590		82	15 91	24 3	2 2	172			
106	128	albabli	290	160	190?	ALL/CSS		5 84		1 6	27 9	440		51 1	10 66	42 4	4.2	167			
107	129	Alwan	350	84	72	CSS		6 9		1 2	24 9	690		51 1	29 56	62 7	4 4	238			
108	132	Shamlan	360	180	80	TV		7.2	'1 6		27 5	560		54	11 39	94 7	6 6	186			
109	138	amr,electric	200			ALL/CSS		7 05		3 7	26 4	710		60 1	20 29	62 8	3 7	224			
110	146	alsyla end	D/DR 160	120		ALL		7 28		1 2	25 1	890		61	21 89	112 5	2 8	193			

ABBREVIATION FOR AQUIFERS

ALL	Alluvial
QV	Quaternary volcanic
TV	Tertiary volcanic
CSS	Cretceous sandstone
AMR	Amran limestone

TRITIUM ANALYSIS RESULTS

WELL NO	
18	<9
21	14+-5
22	12+-5
23	14+-5
47	<9


Millions)
Thousand

Appendix G

(G-1 TO G-15)

Groundwater Regime data

SANA'A BASIN

	RECHARGE COMPONENTS M3			TOTAL	ABSTRACTION COMPONENTS m3			TOTAL
	Wadi Recharge	Irrigation Recharge	Urban recharge dom+indus	RECHARGE	Urban Abstraction	irrigation Abstraction	Rural abstr	ABSTRACTIO
1974	42,574,765	6,233,044	2,319,187	51,126,996	3,957,833	17,945,499	2,254,788	24,158,120
1975	89,397,364	7,011,509	2,594,605	99,003,478	4,394,250	20,591,477	2,376,546	27,362,273
1976	17,789,773	7,789,974	2,870,023	28,449,770	4,830,667	23,230,879	2,504,880	30,566,426
1977	128,690,205	8,568,438	3,145,442	140,404,085	5,267,084	25,863,353	2,640,143	33,770,579
1978	8,738,086	9,346,903	3,420,860	21,505,850	5,703,500	28,488,530	2,782,702	36,974,732
1979	6,051,118	10,125,368	4,370,069	20,546,554	7,088,917	31,105,992	2,932,976	41,127,885
1980	23,140,709	10,903,832	6,936,089	40,980,630	10,751,534	33,715,346	3,091,358	47,558,238
1981	33,137,711	11,682,297	7,201,425	52,021,433	11,173,750	36,316,150	3,258,291	50,748,191
1982	82,908,103	12,460,762	8,280,209	103,649,073	12,741,667	38,907,938	3,434,239	55,083,844
1983	120,420,044	13,239,226	9,073,927	142,733,197	13,908,084	41,490,226	3,619,688	59,017,997
1984	27,745,868	14,017,691	11,299,871	53,063,430	17,091,720	44,062,498	3,815,152	64,969,370
1985	24,496,481	17,473,707	11,051,068	53,021,256	16,862,160	56,014,878	4,021,169	76,898,207
1986	50,740,920	30,962,901	8,854,354	90,558,176	16,748,220	67,956,132	4,238,312	88,942,664
1987	5,528,165	22,450,589	9,551,945	37,530,699	17,851,610	79,968,306	4,384,535	102,204,450
1988	19,323,058	17,408,097	11,297,476	48,028,631	20,430,972	91,975,437	4,535,801	116,942,209
1989	13,433,453	25,321,889	11,746,744	50,502,086	21,184,610	103,977,349	4,692,286	129,854,245
1990	3,048,318	22,336,741	12,663,281	38,048,340	22,596,375	115,973,845	4,854,169	143,424,390
1991	2,853,518	16,262,188	14,065,549	33,181,255	24,692,268	127,306,629	5,021,638	157,020,535
1992	31,505,327	61,508,762	17,472,489	110,486,579	29,611,643	138,633,635	5,194,885	173,440,162
1993	38,895,734	46,678,211	16,849,315	102,423,260	28,854,801	149,954,692	5,374,108	184,183,600
	38520935.99	18,589,107	8,753,196	65,863,239	14,787,083	63,673,940	3,751,383	82,212,406

WADI RECHARGE

	A	B	C	dhar	Hamdan	Gabir	hiz	akhw	gyman	asfal	rawna	rujam	alsir	almahrir	
1974	1077280	17725674	10828443	4132465	347157	219421	457636	1195100	1160762	2077955	640369	309920	1849916	552665	42574765
1975	1946862	26851139	21914284	16803517	1296393	990142	1005343	2750792	2677183	4762434	1469716	726036	4171461	2032062	89397364
1976	293131	4459209	2422992	3896960	343838	172160	531347	861779	830073	1576153	467310	233682	1414385	286754	17789773
1977	2182370	43811195	38273456	14201098	1104027	712756	6140205	2978135	2847390	6406227	1621653	989292	5251366	2171034	1.29E+08
1978	367641	3355720	780347	1401687	182679	59709	5716	330459	263928	535846	232192	69788	786636	365738	8738086
1979	41835	273978	0	2309094	224728	135151	43004	480904	419996	800668	294834	118525	878152	30249	6051118
1980	732542	8959915	4336016	4562330	388732	251143	108482	490469	443698	852242	286753	122509	876364	729516	23140709
1981	620705	7522011	3130358	7634126	531573	323611	1268529	1836788	1775520	3386892	992961	507653	2988643	618342	33137711
1982	1342011	30578977	26621962	8580278	672588	426989	1479781	1924986	1860941	3547056	1036775	533239	3087802	1214718	82908103
1983	2190742	41573021	40841177	12111656	724711	552567	2107614	3007283	3030913	5471991	1529277	856813	4265657	2156622	1.2E+08
1984	587300	8561482	7807562	3349817	271206	201705	1276695	789544	789549	1610497	401621	252419	1230780	615692	27745868
1985	527466	9526089	7227042	2455288	234210	131417	108702	610640	561693	1023351	357195	143521	1098063	491804	24496481
1986	1071634	20666965	15104661	1992373	214766	92106	1194319	1521557	1500328	2811341	791695	427362	2336575	1015238	50740920
1987	164472	1494095	97842	740210	88429	32279	13259	425915	364888	701402	269247	88373	892040	155714	5528165
1988	563336	8075178	4923491	606450	89199	14132	236003	689632	648097	1196574	388320	170328	1164377	557942	19323058
1989	257720	1996346	1333057	3450755	234034	156393	289421	916125	895269	1568236	486258	242201	1347537	260103	13433453
1990	148815	1040517	277862	405461	68085	9333	8955	149870	133041	248072	91941	28111	313383	124871	3048318
1991	0	0	0	2378560	245560	124186	0	8564	6298	13810	6683	0	69858	0	2853518
1992	656392	5702729	2331637	7182524	647794	461474	809808	2173746	2130971	3820729	1147673	585843	3227513	626495	31505327
1993	850313	12328450	9391470	6307141	518412	350141	454373	1303233	1263865	2236131	705375	341123	1991815	853891	38895734
	781128	12725134	9882183	5225089	421406	270841	876960	1222276	1180220	2232380	660892	337337	1962116	742973	38520936

IRRIGATION RECHARGE

	A	B	C	DHAR	HAMDAN	GABIR	HIZYZ	AKHWAR	GYMA	ASFAL	RAWNA	RUJAM	ASSIR	ALMAHJIR	
1974	300949	1598647	2102210	361329	19888	55150	46720	180641	139220	299041	117014	180991	447491	30339	5879629
1975	342090	1816800	2410047	413574	23014	63089	54191	205305	159997	341527	133337	205700	509040	35008	6712719
1976	383094	2034245	2717075	465527	26113	70986	61591	229889	180633	383805	149591	230328	570368	39640	7542886
1977	423964	2250997	3023377	517194	29185	78840	68923	254394	201129	425879	165779	254878	631481	44236	8370256
1978	464701	2467057	3328997	568573	32230	86652	76186	278820	221486	467748	181901	279348	692379	48795	9194873
1979	518369	2751634	3465561	636754	36312	97013	85942	310995	248606	523186	203197	311581	772673	54891	10016712
1980	603141	3201000	3198844	745509	42910	113527	101754	361806	292092	611351	236956	362482	899641	64714	10835725
1981	643165	3413333	3506252	795597	45846	121147	108740	385809	311852	652267	252751	386529	959422	69121	11651830
1982	698746	3708098	3610565	865909	50031	131835	118730	419134	339756	709512	274771	419914	1042539	75380	12464921
1983	748647	3972789	3785366	928655	53733	141377	127554	449057	364575	760693	294498	449892	1117111	80929	13274876
1984	825938	4382593	3604379	1027092	59647	156333	141697	495391	403782	840671	325195	496309	1232779	89753	14081559
1985	966859	5129358	5273247	1209643	70868	184033	168651	579838	477150	988223	381516	580905	1444077	106405	17560773
1986	1643161	8716066	10210703	2064606	121702	314002	289980	985335	816319	1684449	649392	987136	2455348	182452	31120650
1987	1171510	6213348	7658954	1478361	87680	224766	209169	702439	585908	1204539	463721	703716	1751406	131249	22586766
1988	908933	4820146	5930092	1151244	68633	174983	163897	544954	457178	936946	360270	545939	1359412	102607	17525234
1989	1303540	6912248	8862768	1654930	98985	251496	236528	781501	658036	1345901	517122	782910	1950101	147864	25503929
1990	1142254	6056609	7913173	1453088	87155	220789	208373	684777	578406	1181020	453474	686008	1709202	130103	22504430
1991	831524	4408779	5761108	1059522	63692	160969	152343	498477	422115	860714	330311	499371	1244469	95026	16388421
1992	3198661	16958482	21093870	4082887	246031	620213	588753	1917440	1628160	3314988	1271444	1920871	4788102	366855	61996757
1993	2385691	12648051	16540096	3047217	183791	462866	439889	1430084	1215594	2473599	948528	1432640	3571429	273988	47053464
AVERAGE	975247	5173014	6199834	1226361	72372	186503	172481	584804	485100	1000303	385538	585872	1457424	108468	18613320

URBAN RECHARGE	C
1974	2319187
1975	2594605
1976	2870023
1977	3145442
1978	3420860
1979	4370069
1980	6936089
1981	7201425
1982	8280209
1983	9073927
1984	11299871
1985	11051068
1986	8854354
1987	9551945
1988	11297476
1989	11746744
1990	12663281
1991	14065549
1992	17472489
1993	16849315
	8753196

TOTAL RECHARGE FOR EACH ZONE

	A	B	C	dhar	Hamdan	Gabir	hiz	akhw	gyman	asfal	rawna	rujam	alsir	almahrir	
1974	1378229	19324321	15249840	4493794	367045	274571	504356	1375741	1299982	2376996	757384	490911	2297407	583004	50773580
1975	2288952	28667939	26918937	17217092	1319407	1053232	1059534	2956097	2837181	5103960	1603052	931736	4680501	2067070	98704688
1976	676224	6493454	8010091	4362487	369951	243146	592938	1091668	1010706	1959957	616901	464010	1984754	326395	28202682
1977	2606334	46062192	44442275	14718292	1133212	791596	6209128	3232529	3048519	6832106	1787432	1244170	5882847	2215270	1.4E+08
1978	832342	5822777	7530205	1970261	214909	146361	81902	609280	485414	1003594	414093	349136	1479015	414533	21353820
1979	560204	3025612	7835629	2945848	261040	232163	128945	791899	668602	1323854	498030	430106	1650825	85140	20437898
1980	1335682	12160915	14470948	5307839	431642	364670	210236	852274	735789	1463592	523709	484991	1776005	794230	40912523
1981	1263870	10935344	13838036	8429723	577419	444758	1377269	2222597	2087372	4039159	1245712	894182	3948065	687464	51990967
1982	2040758	34287075	38512736	9446188	722618	558824	1598510	2344119	2200697	4256568	1311546	953153	4130341	1290098	1.04E+08
1983	2939389	45545810	53700470	13040311	778444	693944	2235167	3456340	3395487	6232684	1823775	1306705	5382768	2237551	1.43E+08
1984	1413238	12944075	22711812	4376909	330853	358039	1418392	1284935	1193331	2451168	726816	748728	2463559	705445	53127298
1985	1494325	14655447	23551356	3664931	305078	315450	277353	1190478	1038843	2011574	738712	724426	2542140	598209	53108321
1986	2714795	29383031	34169718	4056979	336468	406108	1484299	2506892	2316647	4495790	1441087	1414499	4791923	1197689	90715925
1987	1335981	7707443	17308741	2218571	176109	257045	222428	1128354	950796	1905941	732968	792088	2643446	286963	37666876
1988	1472269	12895324	22151059	1757693	157832	189115	399900	1234586	1105275	2133520	748590	716267	2523789	660548	48145768
1989	1561259	8908593	21942569	5105685	333018	407889	525948	1697626	1553305	2914137	1003380	1025111	3297638	407967	50684126
1990	1291070	7097126	20854316	1858549	155240	230122	217328	834646	711447	1429092	545415	714118	2022585	254975	38216029
1991	831524	4408779	19826657	3438082	309252	285154	152343	507041	428413	874524	336994	499371	1314327	95026	33307488
1992	3855053	22661210	40897997	11265411	893826	1081687	1398561	4091186	3759131	7135717	2419116	2506714	8015615	993350	1.11E+08
1993	3236005	24976501	42780881	9354358	702203	813007	894262	2733317	2479459	4709730	1653902	1773763	5563244	1127879	1.03E+08
	1756375	17898148	24835214	6451450	493778.3	457344	1049440	1807080	1665320	3232683	1046431	923209.3	3419540	851440.3	65887453

Rural abstraction

	A	B	C	DHAR	HAMDAN	GABIR	HIZYZ	AKHWAR	GYMA	ASFAL	RAWNA	RUJAM	ASSIR	ALMAHJIR	Average
1974	114475	593019	471976	248655	23458	36595	60053	67559	121044	176405	57238	67559	184849	31903	2254788
1975	120657	625042	497463	262083	24725	38571	63295	71207	127580	185930	60328	71207	194831	33626	2376546
1976	127172	658795	524326	276235	26060	40653	66713	75053	134469	195971	63586	75053	205352	35441	2504880
1977	134040	694370	552639	291152	27467	42849	70316	79105	141731	206553	67020	79105	216441	37355	2640143
1978	141277	731863	582480	306873	28950	45162	74113	83377	149383	217706	70639	83377	228128	39372	2782702
1979	148907	771386	613936	323445	30514	47601	78115	87879	157451	229463	74453	87879	240448	41499	2932976
1980	156948	813041	647088	340911	32161	50172	82333	92625	165953	241854	78474	92625	253432	43740	3091358
1981	165423	856945	682031	359320	33898	52881	86779	97627	174914	254914	82711	97627	267117	46101	3258291
1982	174356	903221	718861	378724	35729	55737	91465	102899	184360	268680	87178	102899	281542	48591	3434239
1983	183771	951994	757679	399175	37658	58746	96404	108455	194315	283188	91886	108455	296745	51215	3619688
1984	193695	1003402	798594	420730	39692	61919	101610	114312	204808	298480	96847	114312	312769	53981	3815152
1985	204154	1057586	841718	443450	41835	65262	107097	120484	215868	314598	102077	120484	329659	56895	4021169
1986	215179	1114695	887171	467396	44094	68787	112881	126991	227525	331587	107589	126991	347460	59968	4238312
1987	222602	1153153	917778	483521	45615	71160	116775	131372	235375	343026	111301	131372	359448	62037	4384535
1988	230282	1192936	949441	500203	47189	73615	120804	135904	243495	354861	115141	135904	371849	64177	4535801
1989	238227	1234093	982197	517460	48817	76154	124971	140593	251895	367103	119113	140593	384678	66391	4692286
1990	246446	1276669	1016083	535312	50501	78782	129283	145443	260586	379769	123223	145443	397949	68682	4854169
1991	254948	1320714	1051138	553780	52243	81500	133743	150461	269576	392871	127474	150461	411678	71051	5021638
1992	263744	1366278	1087402	572886	54046	84311	138357	155652	278876	406425	131872	155652	425881	73502	5194885
1993	272843	1413415	1124917	592650	55910	87220	143131	161022	288498	420446	136421	161022	440574	76038	5374108
	190457	986631	785246	413698	39028	60884	99912	112401	201385	293491	95229	112401	307542	53078	3751383

IRRIGATION ABSTRACTION

	A	B	C	DHAR	HAMDAN	GABIR	HIZYZ	AKHWAR	GYMA	ASFAL	RAWNA	RUJAM	ASSIR	ALMAHJIR	
1974	918541	4879307	6416257	1102828	60701	168325	142596	551342	424920	912717	357144	552411	1365810	92599	17945499
1975	1049371	5573092	7392895	1268652	70596	193528	166231	629780	490796	1047644	409014	630991	1561496	107389	20591477
1976	1179867	6265149	8368157	1433750	80423	218625	189691	708022	556319	1182057	460717	709374	1756643	122086	23230879
1977	1310011	6955382	9341968	1598084	90178	243608	212967	786055	621471	1315928	512244	787549	1951222	136685	25863353
1978	1439785	7643697	10314252	1761613	99857	268474	236048	863870	686230	1449228	563585	865506	2145203	151181	28488530
1979	1609747	8544952	10761986	1977382	112762	301264	266884	965766	772023	1624708	631009	967586	2399465	170459	31105992
1980	1876671	9959908	9953198	2319651	133516	353238	316606	1125758	908844	1902217	737288	1127862	2799232	201357	33715346
1981	2004601	10638596	10928205	2479698	142892	377588	338919	1202479	971974	2032969	787767	1204724	2990303	215435	36316150
1982	2181063	11574438	11269999	2702845	156165	411509	370602	1308282	1060512	2214668	857670	1310718	3254175	235290	38907938
1983	2339875	12416833	11831048	2902483	167941	441871	398665	1403513	1139467	2377523	920445	1406124	3491497	252941	41490226
1984	2584435	13713537	11278434	3213867	186640	489181	443382	1550123	1263473	2630537	1017566	1552997	3857479	280846	44062498
1985	3084060	16361488	16820459	3858485	226053	587023	537959	1849553	1522000	3152208	1216951	1852954	4606277	339408	56014878
1986	3588064	19032704	22296444	4508345	265753	685665	633210	2151611	1782543	3678220	1418036	2155545	5361584	398408	67956132
1987	4147723	21998322	27116479	5234127	310431	795784	740561	2486980	2074404	4264662	1641802	2491501	6200843	464685	79968306
1988	4770238	25296953	31122141	6041924	360199	918342	860160	2860011	2399351	4917251	1890758	2865184	7134428	538498	91975437
1989	5314420	28180647	36132754	6747008	403552	1025328	964304	3186113	2682757	5487123	2108264	3191857	7950396	602827	1.04E+08
1990	5886469	31211996	40779576	7488314	449141	1137808	1073825	3528913	2980746	6086241	2336922	3535257	8808164	670472	1.16E+08
1991	6459346	34247766	44752775	8230458	494764	1250419	1183415	3872211	3279023	6686095	2565884	3879157	9667143	738172	1.27E+08
1992	7152664	37921595	47168917	9129920	550162	1386886	1316536	4287671	3640800	7412788	2843131	4295343	10706882	820341	1.39E+08
1993	7602961	40308075	52711634	9711178	585724	1475108	1401883	4557534	3873976	7883113	3022862	4565682	11381788	873173	1.5E+08
AVERAGE	3324995	17636222	21337879	4185531	247372	636479	589722	1993779	1656581	3412895	1314953	1997416	4969502	370613	63673940

Urban abstraction	Region C
1974	3957833
1975	4394250
1976	4830667
1977	5267084
1978	5703500
1979	7088917
1980	10751534
1981	11173750
1982	12741667
1983	13908084
1984	17091720
1985	16862160
1986	16748220
1987	17851610
1988	20430972
1989	21184610
1990	22596375
1991	24692268
1992	29611643
1993	28854801
average	14787083

TOTAL ABSTRACTION

	A	B	C	DHAR	HAMDAN	GABIR	HIZYZ	AKHWAR	GYMA	ASFAL	RAWNA	RUJAM	ASSIR	ALMAHJIR	
1974	1033016	5472326	10846067	1351484	84159	204920	202649	618901	545964	1089122	414382	619970	1550659	124502	24158120
1975	1170028	6198135	12284608	1530734	95321	232099	229527	700988	618376	1233575	469342	702198	1756327	141015	27362273
1976	1307039	6923944	13723150	1709985	106483	259278	256405	783074	690789	1378028	524303	784426	1961995	157528	30566426
1977	1444051	7649752	15161691	1889236	117645	286457	283283	865161	763201	1522481	579264	866654	2167663	174040	33770579
1978	1581062	8375561	16600232	2068486	128808	313636	310161	947247	835614	1666934	634224	948883	2373331	190553	36974732
1979	1758654	9316338	18464838	2300827	143276	348865	344999	1053646	929473	1854171	705463	1055465	2639913	211957	41127885
1980	2033619	10772949	21351820	2660562	165677	403410	398940	1218383	1074797	2144071	815762	1220487	3052664	245097	47558238
1981	2170024	11495541	22783986	2839018	176790	430469	425698	1300106	1146888	2287883	870479	1302351	3257421	261537	50748191
1982	2355419	12477658	24730527	3081569	191894	467246	462068	1411180	1244872	2483348	944848	1413617	3535717	283881	55083844
1983	2523646	13368828	26496811	3301658	205599	500617	495069	1511968	1333782	2660712	1012330	1514579	3788242	304156	59017997
1984	2778130	14716940	29168748	3634597	226332	551099	544992	1664435	1468281	2929018	1114413	1667309	4170249	334827	64969370
1985	3288214	17419074	34524337	4301935	267888	652285	645056	1970037	1737868	3466806	1319028	1973439	4935936	396304	76898207
1986	3803243	20147399	39931835	*4975741*	*309846*	*754452*	*746091*	*2278601*	*2010068*	*4009807*	*1525625*	*2282536*	*5709045*	*458376*	*88942664*
1987	4370325	23151475	45885867	5717648	356046	866944	857336	2618352	2309779	4607689	1753103	2622873	6560291	526722	1.02E+08
1988	5000520	26489890	52502554	6542127	407388	991956	980963	2995915	2642846	5272112	2005899	3001088	7506277	602675	1.17E+08
1989	5552647	29414739	58299561	7264468	452369	1101482	1089275	3326705	2934653	5854226	2227378	3332450	8335074	669219	1.3E+08
1990	6132915	32488665	64392034	8023626	499643	1216590	1203108	3674356	3241332	6466010	2460145	3680700	9206113	739154	1.43E+08
1991	6714294	35568480	70496181	*8784238*	*547007*	*1331919*	*1317158*	*4022672*	*3548599*	*7078965*	*2693358*	*4029618*	*10078821*	*809223*	*1.57E+08*
1992	7416407	39287874	77867962	9702805	604208	1471197	1454893	4443323	3919676	7819212	2975003	4450995	11132763	893843	1.73E+08
1993	7875803	41721490	82691352	10303828	641634	1562328	1545014	4718556	4162474	8303559	3159284	4726704	11822362	949211	1.84E+08
average	3515453	18622853	36910208	4599229	286401	697363	689634	2106180	1857967	3706386	1410182	2109817	5277043	423691	82212406

ANNUAL DIFFERENCE= RECHARGE- ABSTRACTION

	A	B	C	DHAR	HAMDAN	GABIR	HIZYZ	AKHWAR	GYMA	ASFAL	RAWNA	RUJAM	ASSIR	ALMAHJI
1974	345213	13851994	4403773	3142310	282886	69651	301707	756840	754019	1287874	343002	-129059	746748	458502
1975	1118924	22469804	14634329	15686357	1224086	821133	830007	2255109	2218804	3870386	1133710	229538	2924173	1926055
1976	-630815	-430490	-5713059	2652502	263468	-16132	336533	308594	319917	581930	92598	-320416	22758	168867
1977	1162284	38412440	29280584	12829056	1015566	505139	5925846	2367369	2285318	5309625	1208168	377515	3715184	2041230
1978	-748720	-2552784	-9070027	-98226	86101	-167275	-228258	-337967	-350200	-663340	-220131	-599747	-894316	223980
1979	-1198450	-6290726	-1.1E+07	645020	117764	-116702	-216054	-261747	-260871	-530317	-207432	-625359	-989088	-126817
1980	-697937	1387966	-6880872	2647277	265965	-38740	-188704	-366109	-339007	-680478	-292053	-735496	-1276659	549133
1981	-906154	-560198	-8945950	5590705	400629	14289	951570	922491	940484	1751275	375233	-408169	690644	425927
1982	-314661	21809417	13782209	6364619	530725	91579	1136443	932939	955824	1773220	366698	-460464	594623	1006217
1983	415744	32176983	27203660	9738652	572845	193327	1740098	1944372	2061705	3571972	811445	-207874	1594526	1933395
1984	-1364892	-1772865	-6456936	742312	104521	-193061	873400	-379500	-274950	-477850	-387597	-918581	-1706690	370618
1985	-1793889	-2763627	-1.1E+07	-637004	37191	-336836	-367703	-779559	-699025	-1455232	-580316	-1249013	-2393796	201905
1986	-1088447	9235632	-5762117	-918762	26622	-348344	738208	228291	306580	485983	-84538	-868037	-917121	739313
1987	-3034344	-1.5E+07	-2.9E+07	-3499078	-179937	-609899	-634909	-1489998	-1358982	-2701748	-1020135	-1830785	-3916845	-239759
1988	-3528251	-1.4E+07	-3E+07	-4784433	-249555	-802841	-581064	-1761329	-1537571	-3138592	-1257309	-2284821	-4982488	57874
1989	-3991388	-2.1E+07	-3.6E+07	-2158783	-119350	-693593	-563327	-1629079	-1381348	-2940089	-1223997	-2307339	-5037436	-261252
1990	-4841845	-2.5E+07	-4.4E+07	-6165077	-344402	-986468	-985780	-2839709	-2529885	-5036918	-1914730	-2966582	-7183528	-484179
1991	-5882770	-3.1E+07	-5.1E+07	-5346156	-237755	-1046764	-1164815	-3515631	-3120186	-6204442	-2356365	-3530247	-8764494	-714197
1992	-3561354	-1.7E+07	-3.7E+07	1562606	289618	-389511	-56333	-352137	-160545	-683495	-555886	-1944281	-3117148	99506
1993	-4639798	-1.7E+07	-4E+07	-949470	60569	-749321	-650752	-1985239	-1683015	-3593829	-1505381	-2952941	-6259118	178668
average	-1759078	-724704	-1.2E+07	1852221	207378	-240019	359806	-299100	-192647	-473703	-363751	-1186608	-1857504	427749

CUMULATIVE DIFFERENCE

	A	B	C	DHAR	HAMDAN	GABIR	HIZYZ	AKHWAR	GYMA	ASFAL	RAWNA	RUJAM	ASSIR	ALMAHJI
1974	345213	13851994	4403773	3142310	282886	69651	301707	756840	754019	1287874	343002	-129059	746748	458502
1975	1464137	36321799	19038102	18828667	1506972	890784	1131714	3011949	2972823	5158260	1476711	100478	3670922	2384558
1976	833322	35891309	13325043	21481170	1770440	874651	1468247	3320543	3292740	5740189	1569309	-219938	3693680	2553425
1977	1995606	74303749	42605627	34310226	2786006	1379790	7394093	5687912	5578058	11049814	2777478	157578	7408864	4594655
1978	1246885	71750965	33535599	34212000	2872107	1212514	7165835	5349945	5227858	10386474	2557346	-442169	6514548	4818634
1979	48435	65460240	22906391	34857020	2989871	1095813	6949781	5088198	4966987	9856158	2349914	-1067528	5525460	4691817
1980	-649502	66848205	16025519	37504298	3255836	1057073	6761077	4722089	4627980	9175680	2057861	-1803025	4248801	5240950
1981	-1555656	66288008	7079569	43095002	3656465	1071361	7712647	5644580	5568463	10926955	2433094	-2211194	4939445	5666877
1982	-1870317	88097425	20861778	49459621	4187189	1162940	8849090	6577520	6524288	12700175	2799792	-2671658	5534068	6673094
1983	-1454573	1.2E+08	48065438	59198273	4760035	1356267	10589188	8521891	8585992	16272148	3611237	-2879531	7128594	8606489
1984	-2819465	1.19E+08	41608501	59940585	4864556	1163206	11462588	8142391	8311043	15794298	3223640	-3798112	5421904	8977107
1985	-4613355	1.16E+08	30635520	59303581	4901747	826370	11094885	7362832	7612017	14339066	2643324	-5047125	3028108	9179013
1986	-5701802	1.25E+08	24873403	58384818	4928368	478026	11833093	7591122	7918597	14825049	2558786	-5915162	2110987	9918326
1987	-8736146	1.1E+08	-3703723	54885740	4748432	-131872	11198185	6101124	6559615	12123301	1538651	-7745947	-1805858	9678567
1988	-1.2E+07	95934950	-3.4E+07	50101307	4498877	-934713	10617121	4339795	5022044	8984709	281342.2	-1E+07	-6788346	9736440
1989	-1.6E+07	75428804	-7E+07	47942524	4379526	-1628306	10053794	2710716	3640696	6044619	-942655	-1.2E+07	-1.2E+07	9475189
1990	-2.1E+07	50037265	-1.1E+08	41777447	4035124	-2614775	9068015	-128994	1110811	1007701	-2857385	-1.5E+07	-1.9E+07	8991010
1991	-2.7E+07	18877564	-1.6E+08	36431291	3797368	-3661539	7903200	-3644625	-2009375	-5196740	-5213750	-1.9E+07	-2.8E+07	8276813
1992	-3.1E+07	2250900	-2E+08	37993897	4086987	-4051049	7846867	-3996762	-2169921	-5880236	-5769636	-2.1E+07	-3.1E+07	8376319
1993	-3.5E+07	-1.4E+07	-2.4E+08	37044427	4147555	-4800370	7196115	-5982001	-3852935	-9474065	-7275017	-2.4E+07	-3.7E+07	8554988

WADI RECHARGE DISTRIBUTION BETWEEN AQUIFERS

	Q. VOLCANIC	T. VOLACANIC	CRET. S.S	AMRAN L.S	TOTAL
1974	12850585	14110257	8468833	7145089	42574765
1975	21047813	38094625	17776940	12477985	89397364
1976	3661398	9037837	3179463	1911075	17789773
1977	32359889	49789636	27168181	19372499	1.29E+08
1978	2525700	3077029	1629570	1505787	8738086
1979	535408.7	4303586	1092783	119339.9	6051118
1980	6866691	8386076	3931796	3956146	23140709
1981	6335306	17856478	5664207	3281720	33137711
1982	22386536	29302525	18012593	13206449	82908103
1983	30502133	43831460	27188839	18897612	1.2E+08
1984	6409895	11427590	5890954	4017429	27745868
1985	6941295	8097323	5317844	4140019	24496481
1986	14559062	16216219	11094545	8871095	50740920
1987	1141957	2564064	1180684	641459.9	5528165
1988	5662840	5869252	4241161	3549805	19323058
1989	1895092	8016266	2502700	1019396	13433453
1990	778776.1	1151937	631585	486020.7	3048318
1991	356784	2312860	183873.8	0	2853518
1992	5012261	18183175	5651099	2658792	31505327
1993	9452701	16018481	7835833	5588718	38895734
	9564106	15382334	7932174	5642322	38520936

QUATERNARY VOLCANIC RECHARGE

	DHAR	B	TOTAL
1974	619870	12230715	12,850,585
1975	2520528	18527286	21,047,813
1976	584544	3076854	3,661,398
1977	2130165	30229725	32,359,889
1978	210253	2315447	2,525,700
1979	346364	189045	535,409
1980	684350	6182341	6,866,691
1981	1145119	5190187	6,335,306
1982	1287042	21099494	22,386,536
1983	1816748	28685384	30,502,133
1984	502472	5907423	6,409,895
1985	368293	6573001	6,941,295
1986	298856	14260206	14,559,062
1987	111031	1030925	1,141,957
1988	90967	5571873	5,662,840
1989	517613	1377478	1,895,092
1990	60819	717957	778,776
1991	356784	0	356,784
1992	1077379	3934883	5,012,261
1993	946071	8506630	9,452,701
	783763	8780343	9,564,106

CRETACEOUS SANDSTONE RECHARGE

	A	C	ALSIR	RUJAM	ALMAHJIR	HAMDAN	Total
1974	915688	5305937	1812918	232440	38687	163164	8,468,833
1975	1654833	10737999	4088032	544527	142244	609305	17,776,940
1976	249161	1187266	1386098	175262	20073	161604	3,179,463
1977	1855015	18753993	5146339	741969	151972	518893	27,168,181
1978	312495	382370	770903	52341	25602	85859	1,629,570
1979	35560	0	860589	88894	2117	105622	1,092,783
1980	622660	2124648	858837	91882	51066	182704	3,931,796
1981	527599	1533876	2928870	380739	43284	249839	5,664,207
1982	1140710	13044761	3026046	399929	85030	316116	18,012,593
1983	1862131	20012177	4180344	642610	150964	340614	27,188,839
1984	499205	3825705	1206164	189314	43098	127467	5,890,954
1985	448346	3541250	1076102	107641	34426	110079	5,317,844
1986	910889	7401284	2289843	320522	71067	100940	11,094,545
1987	139801	47943	874199	66280	10900	41562	1,180,684
1988	478835	2412511	1141089	127746	39056	41924	4,241,161
1989	219062	653198	1320586	181651	18207	109996	2,502,700
1990	126493	136153	307115	21083	8741	32000	631,585
1991	0	0	68461	0	0	115413	183,874
1992	557933	1142502	3162963	439382	43855	304463	5,651,099
1993	722766	4601820	1951978	255842	59772	243653	7,835,833
	663959	4842270	1922874	253003	52008	198061	7,932,174

Tertiary Volcanic
Recharge

	DHAR	HAMDAN	GABIR	HIZYZ	AKHWAR	GYMAN	ASFAL	RWANA	RUJAM	ALSIR	C	TOTAL
1974	3512595	183993	219421	457636	1195100	1160762	2077955	640369	77480	36998	4547946	14,110,257
1975	14282990	687088	990142	1005343	2750792	2677183	4762434	1469716	181509	83429	9203999	38,094,625
1976	3312416	182234	172160	531347	861779	830073	1576153	467310	58421	28288	1017657	9,037,837
1977	12070933	585134	712756	6140205	2978135	2847390	6406227	1621653	247323	105027	16074851	49,789,636
1978	1191434	96820	59709	5716	330459	263928	535846	232192	17447	15733	327746	3,077,029
1979	1962730	119106	135151	43004	480904	419996	800668	294834	29631	17563	0	4,303,586
1980	3877981	206028	251143	108482	490469	443698	852242	286753	30627	17527	1821127	8,386,076
1981	6489007	281734	323611	1268529	1836788	1775520	3386892	992961	126913	59773	1314750	17,856,478
1982	7293236	356472	426989	1479781	1924986	1860941	3547056	1036775	133310	61756	11181224	29,302,525
1983	10294907	384097	552567	2107614	3007283	3030913	5471991	1529277	214203	85313	17153294	43,831,460
1984	2847344	143739	201705	1276695	789544	789549	1610497	401621	63105	24616	3279176	11,427,590
1985	2086995	124132	131417	108702	610640	561693	1023351	357195	35880	21961	3035357	8,097,323
1986	1693517	113826	92106	1194319	1521557	1500328	2811341	791695	106841	46731	6343958	16,216,219
1987	629178	46868	32279	13259	425915	364888	701402	269247	22093	17841	41094	2,564,064
1988	515482	47276	14132	236003	689632	648097	1196574	388320	42582	23288	2067866	5,869,252
1989	2933142	124038	156393	289421	916125	895269	1568236	486258	60550	26951	559884	8,016,266
1990	344642	36085	9333	8955	149870	133041	248072	91941	7028	6268	116702	1,151,937
1991	2021776	130147	124186	0	8564	6298	13810	6683	0	1397	0	2,312,860
1992	6105146	343331	461474	809808	2173746	2130971	3820729	1147673	146461	64550	979288	18,183,175
1993	5361070	274758	350141	454373	1303233	1263865	2236131	705375	85281	39836	3944418	16,018,481
	4441326	223345	270841	876960	1222276	1180220	2232380	660892	84334	39242	4150517	15,382,334

AMRAN LIMESTONE
RECHARGE

	ALMAHJI	A	B	C	TOTAL
1974	513979	161592	5494959	974560	7,145,089
1975	1889817	292029	8323853	1972286	12,477,985
1976	266682	43970	1382355	218069	1,911,075
1977	2019062	327356	13581471	3444611	19,372,499
1978	340137	55146	1040273	70231	1,505,787
1979	28132	6275	84933	0	119,340
1980	678450	109881	2777574	390241	3,956,146
1981	575058	93106	2331823	281732	3,281,720
1982	1129688	201302	9479483	2395977	13,206,449
1983	2005658	328611	12887636	3675706	18,897,612
1984	572594	88095	2654059	702681	4,017,429
1985	457378	79120	2953088	650434	4,140,019
1986	944171	160745	6406759	1359420	8,871,095
1987	144814	24671	463169	8806	641,460
1988	518886	84500	2503305	443114	3,549,805
1989	241896	38658	618867	119975	1,019,396
1990	116130	22322	322560	25008	486,021
1991	0	0	0	0	0
1992	582640	98459	1767846	209847	2,658,792
1993	794119	127547	3821819	845232	5,588,718
	690964	117169	3944792	889396	5,642,322